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THE NATURE OF THE CHEMICAL ATOM[1]

THERE is probably no subject in physical science that has received more attention or produced a more profound influence on the theories of chemistry and physics during the last few years than that of the constitution of the atom. The problem has been attacked, not only by many of the foremost chemists and physicists of the world, but also by many eminent astronomers and mathematicians. It is one of the most difficult as one of the most important problems with which the chemist is concerned.

The conception of the atom became an important factor in chemical science early in the nineteenth century, when Dalton discovered the laws of definite and multiple proportions and announced his well-known atomic theory. He found that when one chemical element combines with another, it combines in a definite proportion or some integral multiple of that proportion. It was only natural that Dalton should have assumed this definite proportion, which he called an atom, to be an indivisible ultimate particle; and it was only natural that this theory should have prevailed throughout most of the nineteenth century, for, among the most prominent characteristics of the atom are its individuality and its permanency. It behaves in many respects like an indivisible particle.

Recent investigations, however, into the phenomena of the cathode rays, Lenard

[1] An address delivered at a meeting of the Southern California Section of the American Chemical Society, Los Angeles, California, Friday evening, October 22, 1915.

rays, canal rays, the Zeeman effect in the spectrum, X-rays and radioactivity have thrown a flood of light on the constitution of matter, and we now know that the atom is very complex in its structure. We know that certain chemical elements are undergoing changes which involve the actual disintegration of the atoms, a phenomenon accompanied by an evolution of energy far greater than that of any other known phenomenon. It has been definitely determined that in the partial disintegration of the atoms, where the atomic mass is reduced only a few per cent., there is set free, in some cases, more energy in the transformation of one pound of an element than is set free in the combustion of 100 tons of coal. Notwithstanding this enormous evolution of energy, these spontaneous, atomic disintegrations are apparently uninfluenced by external conditions, and move along with as much precision and law as the movement of the stars in their orbits. These remarkable phenomena and the intimate relation of electricity, radiant energy and chemical phenomena to atomic structure have brought the problem of the nature of the atom into great prominence in scientific literature.

The experiments of Crookes on the electric discharge in high vacua may be said to have opened the way for the experimental evidence of the complex nature of the atom. Plücker, Hittorf, Goldstein and others had previously investigated this subject, but the results did not become far reaching in their influence on scientific theories until Crookes published the results of his earlier observations in 1879. He found that, regardless of the nature of the residual gas in the exhausted tube or the nature of the cathode, the rays which are given off at the cathode consist of particles moving in straight lines, that they produce a brilliant glow on phosphorescent substances, that they exert a mechanical force and generate heat rapidly when intercepted, and that their trajectory is altered by the influence of a magnet.

Crookes did not carry these experiments to a successful conclusion, but so remarkable were the results that he concluded that the particles of the cathode rays represent a fourth state of matter which he called radiant matter. He said:

> We have actually touched the borderland where matter and force seem to merge into one another. I venture to think that the greatest scientific problems of the future will find their solution in this borderland and even beyond.

In a later communication he spoke of the "ultimate or rather ultimatissimate particles moving with incredible velocity," and of the possibility that elements with atomic weights higher than that of uranium might dissociate into simpler atoms. These statements were certainly prophetic of the important discoveries which were to follow.

Hertz and Lenard showed that the cathode rays would pass through thin plates of metal. They concluded that these rays, owing to their penetrating power, were a form of radiant energy. Later investigation, however, showed the Lenard rays to be identical with the cathode rays, and that both are due to moving particles.

The discovery of X-rays by Röntgen in 1895 gave a great impetus to the investigations on the electric discharge in high vacua. When the cathode rays are suddenly stopped by matter of any kind X-rays are produced. These rays are a form of radiant energy. The X-rays apparently originate in the interior of the atom, and each atom emits X-rays which are characteristic of its own structure. This subject will be referred to again.

Omitting some less important observations, we now come to the work of J. J. Thomson, 1897. He determined experimentally that the particles of the cathode

rays are neither atoms nor molecules, but are negatively charged particles, or corpuscles as he called them, much smaller than the atom. These experiments showed conclusively that the atom has a complex structure. Thomson measured the amount the particles, or electrons as they are now commonly called, are deflected by magnetic and electric fields of known intensities, and in this way determined the velocity of the particles and the ratio e/m, where e represents the charge and m the mass of a particle. This ratio has been determined by different experimenters, and has been found to be about 1.77×10^7.

In 1897 Zeeman observed that the lines in the spectrum are separated into two or more lines when the source of the light is subjected to the influence of a strong magnetic field. Zeeman and later Lorentz showed that such an effect would be produced if the lines in the spectrum are due to the vibration of electrons. They showed that the displacement would be proportional to the ratio e/m. Then from the amount of displacement the value of e/m was calculated and found to be approximately equal to the value determined by Thomson and others. The Zeeman effect has confirmed in a remarkable manner the existence of electrons, and proved them to be common constituents of all atoms. Various other phenomena show the existence of electrons, but it is unnecessary to consider all of these evidences.

Regardless of the source of the electron, the ratio e/m is constant, and is much larger than the corresponding ratio for the hydrogen ion. The latter ratio is 9,649, or almost 10^4. From the values of these two ratios, it is evident that the charge of the electron is much larger, or its mass is much smaller, than that of the hydrogen ion. Thomson and others have determined the magnitude of the charge of the electron and found it to be of the same order of magnitude as that of the hydrogen ion. The value generally accepted for this charge is 4.7×10^{-10} electrostatic units, or 1.59×10^{-20} electromagnetic units. If the charge of the electron is equal to that of the hydrogen ion, it is evident from the ratios given that the mass of the electron is only about 1/1800 that of the hydrogen ion or atom.

It occurred to Thomson that the exceedingly small mass of the electron might be entirely electrical in its nature. He had previously shown that a moving electric charge has a certain amount of mass which is independent of any matter with which the charge may be associated. He calculated that the mass due to a moving charge is equal to $\frac{2}{3}\ e^2/a$, where e represents the charge and a the radius of the sphere of action of the electron. The work of Thomson indicated clearly that the mass of the electron is purely electromagnetic in its nature, but it was difficult to show this conclusively with the particles of the cathode rays. Thomson calculated the relation of the mass to the velocity, and showed that the mass would increase rapidly as the velocity approached the velocity of light. The phenomena of radioactivity soon made it possible to test this theory.

Since the discovery of radioactivity by Becquerel in 1896, and the actual separation of radium from its ores by Mme. Curie, many eminent chemists and physicists have contributed to the investigations on radioactivity, and various radioactive substances have been discovered and isolated. In every case it has been found that radioactivity is caused by a spontaneous disintegration of the atom, a sort of an atomic explosion accompanied by an unparalleled evolution of energy.

Three types of radiations are given off by radioactive substances, the alpha rays, beta rays and gamma rays. The gamma

rays are a form of radiant energy similar to X-rays.

The beta rays consist of negatively charged particles which are identical with the particles of the cathode rays or electrons. The beta particles are thrown off with enormous velocities, almost equal in some cases to the velocity of light. These high velocities have made it possible to determine more definitely the nature of the mass of the electron. Kaufmann and Bucherer have both determined the velocities and masses of beta particles moving with different velocities. They found that the mass increase is equal to the calculated increase in the mass of a moving electric charge.

These results indicate clearly that the mass of the electron is entirely electromagnetic in its nature, and that the electron is in reality a disembodied electric charge. There is considerable experimental evidence to show that all electric charges are made up of some integral multiple of this charge, and that all electric currents are due to some kind of movements of the electrons. If we substitute the values of e and m in the equation $m = \frac{2}{3}(e^2/a)$, we obtain 2×10^{-13} centimeters as the value of a which represents the radius of the sphere of action of the electron. This value probably does not exceed $\frac{1}{20000}$ of the diameter of the atom.

The alpha rays from radioactive substances also consist of particles, but of an entirely different nature from that of the beta particles. They are slightly deflected by a magnet, and in the opposite direction from that of the beta particles, thus showing them to be positively charged. The ratio of the charge to the mass, that is e/m, has been determined and found to be about 4,820, which is one half the value of e/m for the hydrogen ion. The charge carried by the alpha particle is equal to about 9.3×10^{-10} electrostatic units, which is twice the charge of the hydrogen ion. From the foregoing relations, it is evident that the mass of the alpha particle is equal to four times that of the hydrogen ion, or approximately equal to the mass of the helium atom. Rutherford and Royd determined experimentally that, when the charge is neutralized by the surrounding matter, the alpha particle becomes a neutral atom of helium.

The counting of the alpha particles has confirmed in a remarkable manner previous estimates of the number of atoms and molecules in a given quantity of matter. This difficult experiment was performed by Rutherford and Geiger,[2] who constructed an apparatus which would automatically magnify several thousand times the electrical effect of individual alpha particles. They found that one gram of radium emits 3.4×10^{10}, or 34 billion alpha particles per second, and that one gram of radium in equilibrium with its products emits 1.36×10^{11} alpha particles per second.

Various methods have been employed to calculate the number of atoms and molecules in one cubic centimeter of gas. Probably the most reliable estimates are those based on Millikan's[3] determination of the magnitude of the atomic charge. As already indicated, this value is 1.59×10^{-20} electromagnetic units. It is well known that one electromagnetic unit of charge liberates 1.1657 cubic centimeters of hydrogen gas, at standard conditions of temperature and pressure. Knowing the amount of charge or current required to set free one atom, and that required to set free a known volume of hydrogen, it is a simple matter to calculate the number of atoms in one cubic centimeter. In this way it has been estimated that one cubic centimeter of hydrogen under standard conditions con-

[2] *Proc. Roy. Soc., A,* 81, p. 141, 1908.
[3] *Phys. Rev.,* 32, p. 349, 1911.

tains 5.4×10^{19} atoms, or 2.7×10^{19} molecules. Relative to this value, Millikan[4] says:

> To-day we are counting the number of atoms and molecules in a given mass of matter with as much certainty and precision as we can obtain in counting the inhabitants of a city. No census is correct to more than one or two places in a thousand, and there is little probability that the number of molecules in one cubic centimeter of gas under standard conditions differs by more than that amount from 27.09 billion billion.

One gram of radium in equilibrium with its products emits 1.36×10^{11} alpha particles or atoms of helium per second, or 4.20×10^{18} per year. It has been shown by experiment that one gram of radium in equilibrium produces about 160 cubic millimeters of helium per year. From this it is evident that 160 cubic millimeters contain 4.20×10^{18} atoms, and that one cubic centimeter contains 2.6×10^{19} atoms or molecules. The helium molecule contains but one atom.

Furthermore, one gram of radium itself emits 3.4×10^{10} alpha particles per second. Each atom of radium which emits an alpha particle becomes itself an atom of radium emanation which is a gas. It has been determined that one gram of radium is in equilibrium with 0.6 cubic millimeters of radium emanation. The period of average life of radium emanation is comparatively short, and the fraction which decomposes in one second has been definitely determined. Knowing then the volume which is being decomposed, and hence the volume which is being formed in one second, and knowing the number of atoms produced in one second, it is a simple matter to calculate that one cubic centimeter contains 2.7×10^{19} atoms or molecules. There is but one atom in a molecule of radium emanation.

The enormous number of atoms in a given quantity of matter may be illustrated in the following manner. If the atoms of hydrogen and oxygen in one cubic inch of water were arranged uniformly $\frac{1}{100}$ of an inch apart in a single layer, they would cover all the continents of the earth several hundred times.

Notwithstanding its extremely small size, the atom is complex in its structure, and is made up of parts exceedingly small in comparison with its own size. The problem which now commands so much attention is the determination of the nature and arrangement of these parts. We have seen that the negative electron is a constituent of all atoms, but so far no positively charged particle of similar magnitude has been observed. The alpha particles and the particles of the canal rays are positively charged, but these particles are atomic in their magnitude. Every neutral atom must contain a positive charge or charges equal in magnitude to the sum of the negative charges.

In 1902 Lord Kelvin[5] suggested that the atom consists of a uniform sphere of positive electrification the size of the atom, throughout which are distributed negative electrons of sufficient number to neutralize the positive charge. In 1904 J. J. Thomson[6] developed this theory mathematically and showed under what conditions such an atom would be stable, and how various configurations would cause periodicities in the properties of elements as observed in the Periodic System. Thomson has given us the most elaborate discussion of atomic structure which has yet been offered, and has accounted in a remarkable manner for the chemical and other phenomena which the different atoms exhibit. During the last few years, however, some phenomena have been observed which would be difficult

[4] SCIENCE, January 24, 1913.

[5] *Phil. Mag.*, 3, p. 257, 1902.

[6] *Ibid.*, 7, p. 237, 1904.

to explain on the assumption that the positive charge is atomic in its dimensions.

This brings us to the consideration of an atomic structure which is supported by a considerable amount of experimental work. The theory was advanced in 1911 by Rutherford,[7] and was suggested by some experiments of Geiger and Marsden[8] on the scattering of the alpha particles. They observed that the alpha particles from a radioactive substance are deflected from their paths on passing through thin films of metal. They found that the amount of scattering varied with the velocity of the alpha particles, with the thickness of the metal, and with the atomic weight of the metal. It was observed that an occasional particle was deflected through 90° or more and was actually turned back in its course. In order to account for these occasional large deflections, Rutherford assumed that the positively charged alpha particles come into intimate contact with the atoms of the scattering material, and that the deflections are due to the influence of the two electric fields. This would necessitate that the charges be highly concentrated, so he assumed that the atom consists of an exceedingly small nucleus with a strong positive charge, surrounded by negative electrons distributed throughout the rest of the atom. He then calculated the result of an intimate encounter of an alpha particle with the nucleus of an atom, and found that the path of the particle would assume an hyperbolic curve. He calculated the relative number of alpha particles that would be deflected through different angles, and showed that the number of large deflections would be exceedingly small.

Geiger and Marsden[9] in 1913 made an elaborate series of experiments in order to test these theoretical deductions. They experimented with metals of different thicknesses and different atomic weights, and obtained results in accordance with Rutherford's calculations.

According to the theory of Rutherford, when alpha particles pass through hydrogen gas, an occasional atom of hydrogen should acquire, through an intimate encounter with an alpha particle, a velocity of 1.6 times, or a range of about 4 times that of the alpha particle. Marsden[10] tested this theory experimentally in 1914. He observed that with his apparatus the alpha particles had a range of 20 centimeters, as determined by their scintillations on a screen of zinc sulphide; and that an occasional hydrogen atom produced scintillations as far as 90 centimeters.

Various lines of investigation support the theory that alpha particles, on passing through matter, occasionally come into intimate contact with atomic nuclei, and that the large deflections are due to such encounters. Wilson's[11] photographs of the actual tracks of alpha particles indicate that such encounters occur. The deflections of the alpha particles obey certain laws which have been worked out by Rutherford on the theory that each atom consists of an exceedingly small nucleus with a positive charge surrounded by negative electrons. The nucleus, in many cases, is probably made up of both positive and negative electrons, the positive charge being always in excess. The algebraic, not the arithmetic, sum of the positive and negative charges in the nucleus represents the nuclear charge, and is always equal to the sum of the charges of the negative electrons surrounding the nucleus.

Darwin has calculated from the velocity given to the hydrogen atom by the alpha

[7] *Ibid.*, 21, p. 669, 1911.
[8] *Proc. Roy. Soc., A,* 82, p. 495, 1909.
[9] *Phil. Mag.,* 5, p. 604, 1913.
[10] *Ibid.*, 27, p. 824, 1914.
[11] *Proc. Roy. Soc., A,* 87, p. 277, 1912.

particle that the centers of their nuclei must approach within a distance of 1.7×10^{-13} centimeters. This value then would represent a maximum for the sum of the radii of the nuclei of the hydrogen and helium atoms. Rutherford has suggested that the nucleus of the hydrogen atom may be the long sought positive electron, and that its dimensions may be considerably smaller than half of the maximum dimensions given above.

The small dimensions of the nucleus offer a possible explanation of the fact that most of the mass is concentrated in the nucleus, provided the mass is electromagnetic in its nature. As already observed the electromagnetic mass of a body is $\frac{2}{3}(e^2/a)$, where e is the charge and a the radius. According to this formula the mass increases as the radius decreases. If the mass of the hydrogen atom is to be explained on this basis, the radius of the nucleus must be about $\frac{1}{1800}$ that of the negative electron. Rutherford suggests that there is no experimental evidence contrary to such a view, and that its simplicity has much to commend it.

Assuming the atom to have a structure similar to that suggested by Rutherford, the determination of the nuclear charge or, what amounts to the same thing, the number of external negative electrons becomes an important matter. Geiger and Marsden calculated the nuclear charge from the number of alpha particles deflected through a definite angle by metallic films of known thickness, and found it to be approximately equal to one half the atomic weight times the charge of an electron. Barkla[12] in 1911 experimented on the scattering of X-rays, and determined the number of electrons in a known quantity of matter. These experiments were based on the theory of J. J. Thomson that each electron scatters X-rays independently, and that an expression for the scattering can be given in terms of the number of electrons. In this way the number of electrons in the atoms of several elements was found to be approximately equal to one half the atomic weight in terms of hydrogen.

Various lines of investigation indicate that the number of external negative electrons, and hence the magnitude of the nuclear charge, is approximately equal to one half the atomic weight in terms of hydrogen. In the case of hydrogen, however, it is evident that the number of electrons can not be equal to one half the atomic weight. This has led to an important suggestion by van den Broek,[13] that the number of unit charges on the nucleus, and consequently the number of external negative electrons in any atom may be equal to the number of the corresponding element, when the elements are arranged in the order of increasing atomic weights. For example, hydrogen, the first element, would have one electron and one unit charge on the nucleus; helium, the second element, would have two electrons and two charges on the nucleus; carbon, the sixth element, would have six electrons and six charges on the nucleus, and so on. This number is known as the atomic number, and has become an important constant in chemistry.

Among the most important experiments bearing on the subject of atomic numbers are those of Moseley[14] on the "High Frequency Spectra of the Elements." The interference phenomena of X-rays when reflected from a crystal surface have made it possible to determine the wave-lengths and vibration frequencies of these rays. This subject has been especially investigated by W. H. and W. L. Bragg. There are at least two kinds of X-rays, the K or

[12] *Phil. Mag.*, 21, p. 648, 1911.

[13] *Phys. Zeit.*, 14, p. 33, 1913.

[14] *Phil. Mag.*, 26, p. 1024, 1913; 27, p. 703, 1914.

penetrating rays and the *L* or soft rays. Moseley subjected a large number of the elements to a bombardment of the cathode rays and determined the vibration frequencies of the resulting X-rays. He found that the vibration frequency increases with increase in atomic weight. In the first series of experiments the *K* series of X-rays from the different elements were reflected from a crystal surface, and the spectra photographed. Each element produced two characteristic lines. On passing from one element to the next higher in atomic weight the two lines were shifted toward the violet end of the spectrum. In this way a remarkable relationship was established. Moseley found that the vibration frequency is equal to $A(N-b)^2$, where A is a constant and b is equal to unity. N is a whole number which increases by unity on passing from one element to the next higher in atomic weight. As aluminium is the 13th element, Moseley gave N a value of 13 for this element, and determined the corresponding value of A. With the value of A thus determined, the other elements gave values for N equal to their respective atomic numbers; thus, aluminium 13, silicon 14, calcium 20, iron 26, cobalt 27, nickel 28, and so on up to silver 47. With elements of higher atomic weights, the *L* series of rays were used, and the investigations extended to gold, for which $N=79$. For these rays, five lines were visible instead of two. The same formula could be used, however, by changing the values of the constants A and b.

Moseley found that known elements correspond with all numbers from 13 to 79 except three. These elements may be discovered later. Moseley suggests that the presence of a new element and its place in the periodic system can be quickly determined by this method. These results show that some fundamental property of the atom changes step by step on passing from one element to another in the periodic system. Moseley concluded that as N is equal to the atomic number, it represents the magnitude of the nuclear charge, and that this charge changes by unity on passing from one element to the next. It will be noticed that these results reverse the order of cobalt and nickel, indicating that the magnitude of the nuclear charge is more reliable than the atomic weight as an index of quality.

The theory that the chemical and physical properties of an element are closely related to the nuclear charge of the atom is supported by recent observations on the radio-elements.[15] Some important generalizations relative to the nature of these elements have been made during the last few years, and the large gap in the periodic system between the elements bismuth with an atomic weight of 208 and uranium with an atomic weight of 238 is now occupied by more than 30 radio-elements which are apparently true chemical elements.

As already observed, radioactivity is a property of the atom. It is caused by a disintegration of the atoms. There is, however, no gradual disintegration. Each atom of a radio-element is stable until it undergoes a sort of an explosion and ejects an alpha or beta particle, which changes it to a different atom and a different chemical element. Each radio-element has its own characteristic radioactive constant which represents the fraction of the whole amount which disintegrates in unit time. The reciprocal of this constant represents the period of average life. This period varies from a very small fraction of a second to several billions of years for the different radio-elements.

When a radio-element ejects an alpha

[15] For references see Soddy's "The Chemistry of the Radio-Elements," Vols. 1 and 2.

particle it not only changes to a different element, but the atomic weight of the element is reduced by the weight of the alpha particle, which is 4 units. As the alpha particle carries two units of charge, its ejection removes two units of charge from the nucleus of the atom, which changes the valency of the element and shifts it two places to the left in the periodic system. The emission of a beta particle produces no appreciable change in the atomic weight, but adds one unit of positive charge to the nucleus, which changes the valency and shifts the resulting element one place to the right in the periodic system. For example, uranium in group VI. with an atomic weight of 238 emits an alpha particle and becomes uranium-X_1 in group IV. with an atomic weight of 234; this emits a beta particle and becomes uranium-X_2 in group V. with an atomic weight of 234; this emits a beta particle and becomes uranium-2 in group VI. with an atomic weight of 234; this emits an alpha particle and becomes ionium in group IV. with an atomic weight of 230; this emits an alpha particle and becomes radium in group II.; this emits an alpha particle and becomes radium-emanation in the zero group; and so on through the *A*, *B*, *C*, *D*, *E* and *F* products. The latter product, which is polonium, emits an alpha particle and becomes the end product, which is probably lead. The thorium series and the actinium series pass through cycles similar to that of uranium.

When these elements are arranged in the periodic system, it happens in some cases that several elements occupy a single position in the table. A large amount of work has been done on these elements, and it has been found that in every case, where several elements occupy a single position in the periodic system, they are, so far as known, chemically identical and non-separable. Soddy has suggested the term "isotopes" for such elements.

The behavior of the radio-elements confirms to a remarkable degree the theory that the chemical and physical properties of an element depend more on the nuclear charge of the atom than on the atomic weight. The determination then of the atomic number which represents the magnitude of the nuclear charge of the atom becomes an important problem in chemistry.

This brief but incomplete outline shows that the first great advance in the determination of the nature of the atom has been made. Much work is now being done, but much remains to be done before we can assume a definite structure to the atom. Various hypothetical structures have been suggested, especially by Bohr and Nicholson, who have accounted in a remarkable manner for certain series of spectral lines. Various theories have been suggested to account for the stability of atoms with rotating electrons. These theories are based, both on the arrangement and the manner of rotation of the electron, and on the manner in which an electron radiates energy. A more accurate knowledge of the nature of the atom will probably be necessary before its stability can be satisfactorily explained.

In the disintegration of the radio-elements we have definite evidence of the changes of various elements into other elements. These transformations have brought into prominence again the problem of how the various chemical elements have been built up, and the problem of transmutation again becomes a legitimate problem for the chemist to investigate. When we consider the unparalleled amount of potential energy associated with the atom, and the intimate relation of radiant energy and electricity to atomic structure; and when we consider that the supply of energy is the most fundamental problem

with which mankind is concerned, and that the energy which supplies the world to-day is being derived largely from a rapidly diminishing supply of fuel stored up in the past, it is evident that atomic structure is one of the most fundamental problems with which science is concerned.

I know it would be presumptive to assume that we shall sometimes be able to utilize the energy which is stored up in the atom, and, on the other hand, it would be equally presumptive to assume that the atom is the barrier beyond which science can not go. The history of science contains numerous examples of these barriers which have been placed by scientists themselves, and which in many cases have fallen before the conquest of these same scientists. Maxwell said the "atom is incapable of growth or decay, of generation or destruction." We now know that certain atoms are disintegrating, and new atoms forming continually. Less than a century ago scientists assumed that a "vital force" was essential in the formation of organic compounds. To-day thousands of such compounds are being synthesized in the laboratory, and many useful products are being made which, so far as known, the "vital force" has never produced. When Hertz succeeded in producing electromagnetic waves which are now the basis of wireless telegraphy and telephony, he thought it would be impossible to make use of such waves to transmit signals to any great distance. And so on, the unknown and apparently the unknowable of one generation may become the commonplace knowledge of the next. We do not know to what extent we shall be able to solve the mysteries of the atom, and we are unable to even predict the consequences of such a discovery. We know that the problem is beset with almost insurmountable difficulties, and that our knowledge on the subject can never reach finality.

The interior of the atom is the common ground where chemistry and physics meet, and there is probably no problem before the scientific world to-day that offers greater difficulty or promises greater reward than that of determining the nature and arrangement of the constituents of the atom, and the laws which govern their motion. The discoveries already made in this direction have broadened the range of scientific research, and advanced our knowledge one step farther into the mysteries of nature; and it is largely the mastery of man over the laws of nature which marks the progress of the world.

Willett L. Hardin

Los Angeles, Calif.

ON THE UTILITY OF FIELD LABELS IN HERBARIUM PRACTISE

Routine technique in ordinary herbarium practise has made little advance for many years, in sharp contrast to the highly specialized technique in most other fields of botanical work. It is true that no revolutionary changes are to be expected in herbarium methods, yet the author is convinced that some changes are urgently needed in order that the great herbaria now so rapidly being built up in this and in other countries shall be more generally useful than they are to-day.

It is perhaps a survival of the Linnean idea that the name of the plant was the important thing to record on the specimen, and that all other data were secondary, that is reflected in modern herbarium practise. We have advanced, however, to the point where it is conceded by all botanists that the conventional data, geographic locality, collector and date of collection must be added to each specimen, yet many botanists and collectors do not realize the vital necessity of recording in a form that will be available to other workers essential data regarding the plant itself. The result is that the chief value of most large herbaria, aside from supplying material by which the limits of variation may be determined, or the limits of species decided, and in

supplying material on which the descriptions of new species may be based, is in determining the geographic distribution of various species, their dates of flowering and fruiting, and their collectors. What a relatively small return for the time, labor and money expended in building up any large herbarium! Perhaps the average curator is too conservative, yet conservatism carried to the point of not adding any data to the average mounted herbarium specimen other than the conventional Latin name, geographic locality, collector and date of collection of the plant, is absurd. Yet any one who has had long experience in most herbaria will fully realize that collection after collection received with data in some form about the specimens themselves, is often eventually distributed into the herbarium with most or all of the special data eliminated or at least very greatly abbreviated.

Perhaps the weakest point in all large herbaria is the lack of special data with the mounted specimens. The average herbarium, no matter how large or where located, will yield comparatively little information about the plants themselves other than the data that can be determined from the dried specimens and the conventional data usually recorded. As to the individual species, habit, habitat, altitudinal range, size, except for small plants, relative abundance, odor when fresh, color and odor of the flowers, special characters of the fruits not shown by dried specimens, the presence or absence of milky juice, gums or resins, vernacular names, economic uses, etc., can not be determined from a very high percentage of all extant herbarium material, chiefly because the data covering these points are not recorded by the average collector or botanist, or if recorded are not attached to the mounted herbarium specimen in average herbarium practise.

No botanist, from field work, can intimately learn the special characters of more than a few thousand species of plants, and unless he records special data in some form, he will frequently find his memory at fault regarding this or that character of this or that species. The average herbarium will give him little or no assistance, as so few specimens present any special data regarding the plants themselves. This fault in current herbarium practise is apparently reflected in some of our modern manuals, where, for some species, the size of the plant is not given at all, or is inaccurately given, the color of the flowers ignored, and other data that would be of distinct value to the field botanist, are frequently wanting. It is very probable that many of the vernacular names cited in our manuals are not now in use in the United States except as they are learned from the manuals themselves, that is, book names, and undoubtedly hundreds of vernacular names in more or less common use are unrecorded. Scores of "common names" have no existence except in print, being often merely a translation of the Latin name. How much better it would be to cite an actually used vernacular name, even if known only in a limited region, than to coin a common name by the simple process of translating the Latin one, and thus establishing in print a name that nobody ever uses. Yet probably no herbarium in the United States gives any appreciable amount of data as to vernacular names actually in use for the simple reason that botanists and collectors have neglected to record such names with the specimens.

A herbarium to be of the greatest service should present not only the geographic range of the various species, their period of flowering and fruiting, and when and by whom collected, but also the essential data regarding the individual plants themselves indicated above. In other words a properly prepared herbarium should be a card index to the various aspects of the species represented by dried specimens, their economic uses, vernacular names, and all possible information regarding the individual plants themselves that the dried specimens and usually recorded conventional data do not show.

The local botanist or collector may, and often does, record copious notes in various types of notebooks, but usually such notes are available only to himself, never become actually attached to his herbarium specimens, and ultimately become lost. If the collector does

not attach his notes to his specimens it can hardly be hoped that some other person will do it for him.

Those herbaria that are rich in original collections should present the most data regarding the plants themselves, yet very little attention is given to the eminently practicable and logical procedure of recording notes with the specimens in most herbaria. In almost any large herbarium case after case could be cited where original data regarding the plants themselves recorded on the specimen sheets, on slips of paper, or in notebooks, have deliberately been discarded either because it was not recognized herbarium practise to record such data, or at least to attach the data to the herbarium specimen; because the ultimate value of such data was not realized; because there is no generally recognized place on herbarium sheets for recording miscellaneous data; or perhaps more often because of the time involved in copying data from crude field notes. This brings up a vital phase of the subject, and that is, even if the original data be carefully copied on the herbarium sheet, the *original notes,* no matter how crude, should always be attached to the sheet as a part of the record.

Perhaps one potent reason why in ordinary herbarium practise little special data is recorded with the specimen is that the average herbarium label is too small on which to record more than a small fraction of the data that might or should be recorded with the specimen. In the opinion of the author the conventional herbarium label is no place on which to record other than the data for which it was designed, the name, locality, collector and date of collection. For esthetic reasons many botanists are opposed to writing on the herbarium sheet, and aside from the herbarium label itself, there is no recognized place on the sheet for recording special data. The question of time and labor is also involved, for under common practise special data must be copied from a notebook or compiled from memory. The problem of recording data with the mounted specimen with the least possible loss of time and labor, is solved by the adoption of a field label.

The urgent need of some radical change in current American herbarium practise is not fully realized, and in the matter of recording special data on mounted botanical specimens American institutions are, on the average, about the same as those of other countries. Fifteen years' work in systematic botany in many different herbaria in the United States, in Europe, in Asia and in Malaya, and my own experience in establishing and building up the herbarium of the Bureau of Science in Manila, has led me to prepare the present paper with the hope that it may lead to a higher average of herbarium practise as to the recording of data about the individual species. To give some definite idea of the great lack of special information about the plants themselves, as recorded in the average herbarium, I have compiled data from 3,000 mounted herbarium specimens, taken at random from three types of herbaria. Care was taken in each case, however, so to select the sheets that families presenting trees, shrubs, vines and herbs were included. In one case not less than 75 per cent., and in two cases over 90 per cent. of the sheets represented the original specimens, that is, the first set, whenever duplicates were prepared, and material primarily collected for the institutions to which the herbaria belong. In not a single case did the special data record on any specimen exceed fifteen words on the 3,000 sheets examined, the average certainly not exceeding five words. In separating the specimens into two categories, one with special data and one without, if a single word such as "tree," "forests," "swamp," etc., was added beside the conventional Latin name, locality, collector and date of collection, the specimen was placed in the group with special data.

In a large collection assembled over the course of more than forty years, the combined results of the field work of many botanists and collectors for the purpose of working up a local flora, of 1,000 sheets examined less than 10 per cent. presented any data regarding the plants themselves. Over 90 per cent. presented merely the conventional data, Latin name, locality and date of collection, collector; not a word regarding even the size, habitat or

special characters of the plant or its parts. The botanist who utilizes this large collection for the purpose of writing a local flora must himself go into the field and to a large degree determine anew the special data that should have been accumulating during the past forty years regarding the special characters of each individual species found in the area covered by the collection. To-day nobody can determine what original notes were made by the various collectors, and unquestionably observations or notes were made when most or all of the specimens were actually collected.

In a much larger collection of exotic plants, a collection still apparently rich in species as yet undescribed, and a collection in which at least 75 per cent. of the sheets represent *original* collections, less than 8 per cent. of the sheets bear any data whatever other than the conventional Latin name (so far as the material is identified), collector, locality and date of collection.

In a third collection, a herbarium of economic plants, presenting chiefly those species actually cultivated for agricultural or horticultural purposes, on a basis of 1,000 sheets examined, less than 3 per cent. of the sheets present any data regarding the plants themselves. It is estimated that at least 95 per cent. of this herbarium represents *original* collections.

In contrast to the above three herbaria I wish to cite the one in which I am especially interested, the contrast of which has led me to prepare this paper, and that is the herbarium of the Bureau of Science in Manila. In this herbarium there are now approximately 160,000 mounted sheets, of which about 100,000 are Philippine, the remainder chiefly from surrounding regions. The extra-Philippine material, except that collected by employees of the Bureau of Science, as to special data recorded with the specimens, is quite like similar material received in exchange by other institutions. Taking into consideration only the Philippine material, approximately 75,000 sheets, or 75 per cent. of this part of the herbarium, present special data regarding the plants themselves recorded on field labels of one type or another. These field labels were filled out when the plants were collected, were placed with the specimens in press, remained with the specimens through all processes until the mounted sheet was distributed into the herbarium, and the accumulated data thus recorded has added immensely to the value of the herbarium. The notes with the specimens represent the combined field observations of perhaps 100 different American and Filipino collectors, and the botanist working with this material has at once available a great mass of information that is not to be found at all in the average herbarium, and information that no single collector could possibly secure in any reasonable time. The herbarium is what it ought to be, an index to the various aspects of Philippine botany from both an economic and a scientific standpoint. It is consulted not only by systematic botanists, but also by foresters, agriculturists, horticulturists, philologists and others interested in the economic aspects of botany.

In a very few European herbaria field labels have been used for a number of years, but in general their great utility has been quite overlooked by botanists, collectors and curators of herbaria, and in most herbaria are quite unknown. Every European field label I have seen presents what I consider to be serious defects either in form, in size or in indicated data to be recorded. From my early work in the United States Department of Agriculture I was familiar with the types of labels used for field work in the Division of Agrostology, which were sometimes attached to the mounted sheets, and sometimes not; these labels had a fatal defect in that the attempt was made to combine a field label with a herbarium label, and their use was eventually abandoned. In establishing the botanical work in the Philippines in the year 1902 I was immediately impressed with the necessity of recording data about the plants themselves in such form that it could be recorded with the mounted specimens. The first field label adopted was exceedingly crude and experience on a single field trip proved that it was utterly unadapted to the purpose in view. In the meantime, however, I became acquainted with the forms de-

veloped by Dr. S. H. Koorders for his field work on the forest flora of Java,[1] and a modified form of the smaller type of label used by him was adopted for use in the Philippines early in the year 1903. From

FLORA OF THE PHILIPPINE ISLANDS
HERBARIUM, BUREAU OF SCIENCE

Common name ..... Dialect .....
Field No. ..... Herbarium No. .....
Collector .....
Island of Province .....
Locality .....
Habitat .....
.....
Altitude above the sea .....meters
Tree; shrub, bush; vine; herb .....
Height of plant .....M.
Diameter of plant, breast high .....Cm.
Flower .....
(Odor, color, etc.)
.....
.....
Fruit .....
(Kind, odor, color, etc.)
Special notes .....
.....
Economic uses .....
.....
Date .....

Fig. 1. A Field Label for General Purposes. Actual size 15.5 × 8.5 cm.

time to time changes were made in the arrangement of the printed data on the label, as the field experience of myself and associates seemed to warrant, until the label finally assumed the form presented in Fig. 1, in actual size 15.5 by 8.5 centimeters. Fig. 2 represents a somewhat modified form of the label as adapted to a special purpose, that is, the botanical exploration of Amboina with special reference to data that is essential in interpreting the species figured and described by Rumphius in his "Herbarium Amboinense."

FLORA OF THE MALAY ARCHIPELAGO
HERBARIUM, BUREAU OF SCIENCE, MANILA, P. I.

Common name ..... Dialect .....
Field No. ..... Herbarium No. .....
Collector, C. B. Robinson
Island .....
Locality .....
Habitat .....
Altitude above the sea .....M.
Tree; shrub; woody vine; herbaceous vine; herb ..
.....
Height of plant ..... m.; diameter .....cm.
Flower .....
.....
Fruit .....
Supposed to represent .....
.....
Rumph. Herb. Amb. .....
.....
Identification considered certain; probable; possible; very doubtful.
Date ....., 19

Fig. 2. A Field Label for a Special Purpose. Actual size 15.5 × 8.5 cm.

The field label as developed for the botanical work in the Philippines is presented not with the idea that it presents, as to printed form and data, the label that is best for general use in other countries, but merely the label that twelve years' experience has shown to be best adapted to our purposes in the Philippines. It is doubtful, however, if the shape and size could be improved upon, but the printed data could be modified to suit the country in which collections are to be made, or to suit the pur-

[1] Merrill, E. D., "Report on Investigations Made in Java in the Year 1902," Philip. Forestry Bureau Bull., 1: 60–63, 1903.

poses of the collector if he confines his field work to special groups of plants. A label, if made too small, will interfere with the proper handling of mounted herbarium specimens if it is attached where it should be placed, that is, at the *upper left-hand corner* of the herbarium sheet. If made too large and complex too much time is involved in properly filling it out. The label now used in the Philippines assumed its present form largely because much of the field work of necessity must be carried on by men with little botanical training. To an inexperienced collector, then, a field label serves as an indicator as to the data that is of the most value, and the data that should be recorded in order that the specimen when finally mounted, shall present as many facts as possible about the plant that are not shown by the dried specimen itself.

I know of no serious objection to the use of field labels, and by their use an enormous mass of most valuable information can be recorded in such form that it will be available to other botanists than the collector, data that is not now being recorded at all, or if recorded is, except in special cases, never attached to the mounted herbarium sheets. From long personal experience with field labels, and judging from the experience of many others who have used them in the Philippines, it is confidently prophesied that the average collector or botanist who adopts a logical compact form for recording his notes on field labels, and who once fully appreciates the advantages and simplicity of the system, will never revert to the now almost universal and decidedly impracticable method of recording notes on the specimen sheets or in a notebook.

Objections that have been offered to the use of field labels are not especially valid. In practise the size adopted in the Philippines will not be found to be too great; it is approximately the size of generally used pocket notebooks; it takes up little space on the mounted sheet, and if properly placed does not in the least obscure the mounted specimen, or interfere with the handling of the herbarium sheets. Scanty or copious notes may be taken at the discretion of the collector. A specially modified form may be adopted for special groups of plants, such as ferns, lichens, fungi, grasses, etc., or for special types of herbaria, such as dendrological collections, agricultural or horticultural plants, etc. The field label is not too complex, and the printed form can be filled out much more rapidly than can a similar amount of data be recorded on a blank page. Under all but the most abnormal field conditions the label can readily be filled out when the plant is collected, or soon after the specimens are placed in press and before the collector's conception of the plant has become dim. To the objection that the labels can not properly be filled out when one is heated and perspiring from field work, I can merely point to the 40,000 specimens in the Javan collections of Koorders, and nearly twice this number in the Philippine herbarium, all of which were filled out in the field in tropical and not in temperate regions, and often under the most adverse climatic conditions.

If it is considered desirable the labels can be numbered serially before commencing field work, thus avoiding the danger of duplicating or of skipping numbers. In all cases, however, the field label should be placed with the specimen it describes in press, and should remain with the specimen under all circumstances and through all processes until the mounted sheet is distributed into the herbarium. In practise it has been found much more convenient to have the labels perforated at the top, that they may readily be removed, and bound into notebook form, 100 labels to a book. It sometimes happens that it is desirable that the collector retain his notes in serial form. This is very readily accomplished by utilizing a carbon paper and making two copies of the label, one to be removed from the book and placed with the specimen, one to be retained in the book in its serial place; the original label may be white, and the duplicate on pink or yellow paper.

The proper place for the field label on the mounted herbarium sheet is in the *upper left-hand corner*. Here it interferes less with the mounted specimen than in any other position and causes the least trouble in handling the

mounted sheets. It should be attached merely by gumming the lower surface of the upper left-hand corner of the label, and under no circumstances should the entire back of the label be pasted to the sheet. It frequently happens that it is necessary or desirable to record additional data on the back of the label, and again, if merely attached by the upper left-hand corner, the label can then be lifted or turned back should it cover any portion of the specimen that it is necessary or desirable to examine.

The advantages of a comprehensive system of field labels are very great, and their use should appeal to the most conservative botanist. The addition of the field label to the mounted sheet does not detract from the appearance of the mounted specimen, it supplies a proper place for recording data regarding the plant itself that otherwise, if recorded at all, must be abbreviated and crowded on the small herbarium label or laboriously copied on the sheet itself, and if consistently used will preserve in a form available for other contemporary workers as well as for future botanists a mass of information regarding the plants that is now not being recorded at all, or if recorded, is rarely attached to the actual mounted specimens and ultimately becomes lost.

E. D. Merrill
Bureau of Science,
Manila, P. I.

NATIONAL ACADEMY OF SCIENCES

The autumn meeting of the National Academy of Sciences will be held on Monday, Tuesday and Wednesday, November 13, 14 and 15, 1916, in the new buildings of the Massachusetts Institute of Technology, adjoining the Charles River Basin in Cambridge, with headquarters across the Basin at the Harvard Club, 374 Commonwealth Avenue, in the Back Bay district of Boston. Hotels Puritan and Somerset, in the same block with the Harvard Club on Commonwealth Avenue, will be convenient for members accompanied by their families. Luncheon will be provided for members and ladies accompanying them at Riverbank Court, adjoining the Institute buildings on Monday and Tuesday, and at several of the neighboring scientific institutions on Wednesday.

It has been found necessary to postpone the William Ellery Hale lectures, previously announced to be given by Professor E. G. Conklin on Monday evening and Tuesday afternoon, November 13 and 14. The Monday evening lecture will be replaced by an introductory address by President W. H. Welch on the Formation of the National Research Council at the request of the President of the United States and a lecture by Dr. S. W. Stratton, director of the National Bureau of Standards, on the Target Practise in the Navy and some of the Research Problems involved, illustrated with moving pictures. The Tuesday afternoon session will be devoted to reports by members of the National Research Council.

At the close of the Monday evening session a reception will be held by President and Mrs. Maclaurin of the Massachusetts Institute of Technology and President and Mrs. Lowell of Harvard University, in the General Library where a scientific exhibit will be displayed. On Wednesday there will be visits to scientific institutions in and near Boston.

The local committee consists of W. M. Davis, chairman, W. T. Councilman, A. A. Noyes and E. C. Pickering.

The program of papers to be read at the meeting is as follows:

Monday, November 13

From 2.00 to 3.30:

Welcome by President Maclaurin, of the Massachusetts Institute of Technology.

Raymond Pearl, Maine Agricultural Experiment Station. Some Effects of the Continued Administration of Alcohol to the Domestic Fowl, with special Reference to the Progeny. (20 minutes, lantern.)

Edward S. Morse, Salem, Mass. Protoconch of *Solemya*. (10 minutes.)

Alfred G. Mayer, Marine Laboratory, Carnegie Institution. Further Studies of Nerve Conduction. (10 minutes, lantern.)

E. G. Conklin, Princeton University. The Share of Egg and Sperm in Heredity. (10 minutes, lantern.)

Jacques Loeb, Rockefeller Institute. Diffusion and Secretion. (12 minutes.)

Lafayette B. Mendel and S. E. Jordan, Yale University. Some Interrelations between Diet, Growth and the Chemical Composition of the Body. (12 minutes.)

Henry L. Abbot, Cambridge, Mass. Hydrology of the Isthmus of Panama.

John M. Clarke, State Museum, Albany. The Strand and the Undertow.

W. M. Davis, Harvard University. Sublacustrine Glacial Erosion in Montana.

Scientific Exhibit in the General Library, from 3.30 to 5.00.

From 8.15 to 9.15:

President W. H. Welch, Johns Hopkins University. The Formation of the National Research Council at the Request of the President of the United States. (15 minutes.)

Dr. S. W. Stratton, Director of the National Bureau of Standards, Washington. Target Practice in the Navy and Some of the Research Problems Involved; Illustrated with Moving Pictures. (45 minutes.)

Reception and Scientific Exhibit in the General Library, from 9.15 to 10.30.

Tuesday, November 14

From 10.00 to 12.30:

Edwin H. Hall, Harvard University. Electric Conduction in Metals. (20 minutes, lantern.)

Edward B. Rosa, National Bureau of Standards. The Silver Voltameter as an International Standard. (15 minutes.)

R. W. Wood, Johns Hopkins University. One-dimensional Gases and the Reflection of Molecules. Series in Resonance Spectra. (10 minutes, lantern.)

Elihu Thomson, Swampscott, Mass. Inferences Concerning Auroras. (20 minutes.)

A. A. Michelson, University of Chicago. Report of Progress in Experiments for Measuring the Rigidity of the Earth. (10 minutes.) The Laws of Elastico-viscous Flow. (10 minutes.)

C. G. Abbot, Smithsonian Institution. On the Preservation of Knowledge. (5 minutes.)

Franz Boas, Columbia University. Further Evidence Regarding the Instability of Human Types. (20 minutes.)

Ross G. Harrison, Yale University. Transplantation of Limbs. (20 minutes, lantern.)

Chas. B. Davenport, Station for Experimental Evolution, Carnegie Institution. Heredity of Stature. (20 minutes, lantern.)

From 2.30 to 5.00:

Professor George E. Hale, Chairman of the National Research Council. The Work of the National Research Council; Recent Observations of Organized Science in England and France. (45 minutes.)

Lieutenant Colonel George O. Squier, Chief of Aviation, U. S. Army. Scientific Research for National Defense, as Illustrated by the Problems of Aviation. (45 minutes.)

Professor Arthur A. Noyes, Massachusetts Institute of Technology. The Nitrogen Problem in War and in Agriculture. (30 minutes.)

Discussion of the Work of the National Research Council.

SCIENTIFIC NOTES AND NEWS

A MEETING to plan a memorial to the late Sir William Ramsay was held at University College, London, on October 31. After the meeting, the director of the University College Chemical Laboratories, Professor J. Norman Collie, F.R.S., delivered a memorial lecture on "The Scientific Work of Sir William Ramsay."

WE are informed by a correspondent who has just returned from Germany that the published statement that Dr. A. von Wassermann, of the University of Berlin, has succeeded Ehrlich as head of the Institute for Experimental Therapeutics at Frankfort-on-Main is incorrect and that Professor Kolle of Berne, holds this position temporarily.

PROFESSOR WILLIAM W. PAYNE, director of the Elgin Observatory, formerly professor of mathematics and astronomy and director of the Goodsell Observatory of Carleton College, and the founder of *Popular Astronomy,* was granted the degree of doctor of science by Carleton College on October 13, on the occasion of the celebration of the fiftieth anniversary of the founding of the college.

PROFESSOR W. A. NOYES, director of the chemical laboratory of the University of Illinois, will lecture on "The Electron Theory" as part of the program of the Franklin Institute, Philadelphia, for the year 1916–17.

ON October 26, Professor C. J. Keyser delivered an address before the assembly of Le-

land Stanford University on "Ways to Pass the Walls of the World." On October 27, he addressed the university meeting of the University of California on "The Ideals that are Most Worthy of Loyalty." During the current half-year Professor Keyser is giving instruction in the University of California in exchange of work with Professor M. W. Haskell, who is lecturing in Columbia University.

It is reported that Lieutenant-colonel J. George Adami, professor of pathology in McGill University, Montreal, who held the position abroad of official Canadian recorder of medical history of the war, has resigned and will soon return to Montreal.

Mr. John E. Mellish, who has been at the Yerkes Observatory for the past fifteen months as volunteer research assistant, will take charge of the well-equipped private observatory at Leetonia, Ohio, of Mr. Elmer Harrald.

Walter D. Harris, formerly assistant professor of physics at Syracuse University, has resigned his position with the United States Bureau of Chemistry to take an active interest in the Valhalla Co., Chicago, manufacturers of electro-chemical machinery.

Mr. E. W. Kerr has resigned his professorship in mechanical engineering at Louisiana State University to take up commercial work with the Cuba Cane Sugar Corporation, Havana, Cuba.

Dr. Leverett D. Bristol, for two years professor of bacteriology and hygiene and director of the city public health laboratory at the University of North Dakota, has accepted the newly created Boston dispensary fellowship in public health in the department of preventive medicine at Harvard Medical School, Boston.

Sir Ernest Shackelton, the Antarctic explorer, arrived in New Orleans, on November 3, on the steamer *Parismina*, from Colon, and departed several hours later for San Francisco, on his way to rescue ten members of the Shackelton party on the west side of the Antarctic continent. He expected to sail from San Francisco for Wellington, New Zealand, on November 8, going thence to Dunedin, where he and a rescue expedition will sail for the Antarctic on the *Aurora*.

Lieutenant-colonel E. Alexander Mearns, U. S. A., died in Washington, D. C., on November 1, in his sixty-first year. He was one of the founders of the American Ornithologists' Union, and a member of the Roosevelt East African expedition. Dr. Mearns was an indefatigable collector of natural history specimens all his life, and was the author of many contributions to zoology and botany.

Theodore Newell Ely, engineer and retired chief of motive power of the Pennsylvania railroad, died on October 28, at his home at Bryn Mawr, Pa., aged seventy years. Dr. Ely established a scientific department in the Pennsylvania Railroad in 1875. He had received the honorary degree of master of arts from Yale University and the doctorate of science from Hamilton College. In addition to membership in the national engineering societies, he was a member of the American Philosophical Society and a fellow of the American Association for the Advancement of Science.

Phillip H. Cary, a graduate of Oberlin College who had nearly completed the work for the degree of doctor of philosophy at the University of Minnesota, where he was specializing in paleontology and stratigraphy, died on October 27. Last January, when the call came for more men in the southwestern oil fields, he left his graduate work temporarily and was rapidly establishing a reputation as an oil geologist in Oklahoma.

Professor G. C. J. Vosmaer, of the University of Leiden, known to all zoologists for his valuable contributions on the morphology and classification of sponges, has died at the age of sixty-two years.

The death is announced of the distinguished psychiatrist Dr. Magnan, honorary chief physician of the Asile Sainte-Anne at Paris.

The twenty-fifth annual meeting of the American Psychological Association, in affiliation with the American Association for the Advancement of Science, will occur on Wed-

nesday to Saturday, December 27 to 30, in New York City. By invitation of the psychologists of Columbia University the sessions will be held at that institution. It is proposed to hold the regular meetings in Teachers College, 120th Street, between Broadway and Amsterdam Avenue. As headquarters the Hotel Marseilles at 103d Street and Broadway has been selected. This meeting marks the twenty-fifth anniversary of the association's foundation. An appropriate program commemorating the event will be held on Thursday afternoon, December 28. The annual banquet will also take place on Thursday, at 7 P.M., in the Hotel Marseilles. The program of after-dinner speakers for this occasion is in the hands of the anniversary committee. The president's address on "The Laws of Relative Fatigue" will be given by Professor Raymond Dodge, of Wesleyan University, at 8 P.M. on December 27, in Schermerhorn Hall. It will be followed by the annual business meeting of the association, and a smoker in the Psychological Laboratory. A joint session with Section L (Education) of the American Association for the Advancement of Science is planned for Friday morning, December 29. The program with additional notes on the meetings will be distributed to members early in December.

THE formation of the Association of British Chemical Manufacturers has been noted in SCIENCE. The association, which has been joined by the leading chemical firms of Great Britain, is now installed in offices at 166, Piccadilly. Sir Charles Bedford has been appointed general secretary, and Sir William Pearce, M.P., honorary treasurer. The chief objects of the association are: (1) To promote cooperation between British chemical manufacturers. (2) To place before government the views of the association upon matters affecting the industry. (3) To develop technical organization and promote industrial research and efficiency. (4) To facilitate the development of new British industries and the extension of existing ones. (5) To improve the methods of education in chemistry. (6) To finance researches undertaken in the interest of the industry. (7) To found scholarships or lectureships for the promotion of its objects. The financial strength of the association is guaranteed by the fixing of the minimum subscription at 25 guineas and the maximum at 250 guineas. The affairs of the association are to be managed by a council of 20, 16 elected and 4 coopted.

THE New York *Medical Journal* gives the following statistics in regard to the death rate in Germany which, after reaching the low record of 14 per mille in 1913, has followed a steadily ascending curve during the war. The figures for 1914 were 16.1 per mille, in 1915 there was an increase to 19.7, and the record for the first seven months of 1916 is 16. These statistics include civilians and soldiers. Infant mortality, however, continues to follow a descending curve. The number of deaths per centum new births, after showing a slight increase from 14.1 in 1912 and 1913, to 15.6 in 1914, dropped to 14.5 in the first year of the war. For the last year the percentage has been 12.9.

THE rate of growth of trees in woodlots and in plantations in Central New York is being studied by the junior class of the New York State College of Forestry under the direction of Professor J. Fred Baker, director of forest investigations. Soil and climatic conditions in central New York are unexcelled for maintenance and rapid forest growth. In fact, trees grow like weeds in New York and there is not a square foot in the state where there is any soil at all which will not maintain a good forest growth. The so-called virgin forests of the Adirondacks are growing to-day at the rate of about 200 board feet per acre per year. Properly managed forests, such as those of the Black Forests of southwestern Germany, are growing at the rate of from a 1,000 to 1,200 board feet per acre per year. Reasonable use of farm woodlots and the planting of the right kinds of forest trees on forest soils means the production of excellent crops of timber and that within a comparatively short period of time. The planting of trees along the highways of the state is being studied by Professor H. R. Francis, of the Landscape Extension Service of the College of Forestry at Syra-

cuse. Field studies and plans have already been prepared for portions of the main highway between Utica and Albany and the state highway between Utica and Syracuse is now being carefully studied. It is not the idea of Professor Francis to line the highways with straight rows of trees. Natural vistas showing beauty spots away from the highways will be left open, and it will be suggested that other vistas be made so that the highways will not alone be well planted with trees and shrubs, but there will be more nearly a park-like effect with opportunities of seeing the beauty of the country on either side. Professor Francis is urging the use of native trees and shrubs, taking advantage in so far as possible of the material on the ground. It is expected that these studies of highway planting will result in a publication showing just how definite areas of highway may be treated to best advantage. This will supplement a bulletin on "Suggestions for Street Tree Planting" which has already been given wide distribution by the college.

United States patents have been issued to Dr. Clifford Richardson on an improved "bituminous substance" and on the process by which this product is manufactured. Similar patents have also been granted in Canada, Great Britain, France and Italy. It is said that these are the first patents covering a product and process involving the introduction of colloidal matter into bitumens of all types. According to the inventor, he obtains "an increased degree of body or stability in these bituminous substances, by means of the addition to and intimate and uniform dispersion through the bituminous substance of a proper proportion of a substance in the state of a disperse colloid. The process consists in the introduction of clay in the form of a colloidal aqueous paste and combining this paste with the bitumen in such a way that when the water is subsequently driven off, the bitumen forms the continuous phase of the colloidal material. The products resulting from this method of incorporating clay in colloidal form with bitumen has markedly different properties from products into which the mineral matter is introduced in the form of a dry powder. The products made by the Richardson method range all the way from materials resembling vulcanized rubber to plastic, but at the same time very stable mixtures suitable for paving and many other uses.

The *Journal* of the American Medical Association reports that an institute for vaccines, bacteriology and chemistry at Buenos Aires was recently inaugurated. Penna, chief of the public health service, Malbran, chief of the bacteriologic service, and various professors with university chairs in these specialties, all delivered addresses. Magnin, chief of the chemical department, reported that already he had researches under way which might aid materially in remedying the scarcity of imported drugs. A number can be made and many are now being made in the workrooms connected with his department. An isolated pavilion has been set apart for a training school in applied chemistry. The national board of health has had a chemical department since 1880, but this new triple institute is said to be equipped for the science and needs of to-morrow as well as to-day.

UNIVERSITY AND EDUCATIONAL NEWS

The Carborundum Company of Niagara Falls, N. Y., will construct an administration building on lands of the Niagara Falls Power Company on the Niagara River front. It is proposed to tender the use of the present offices to the Massachusetts Institute of Technology, which has decided to establish a research laboratory at Niagara Falls.

Charles Gilman Hyde, professor of sanitary engineering in the University of California, has been appointed acting dean of its college of civil engineering, to serve during the present year because of the absence on account of illness of Professor Charles Derleth, Jr.

The following former members of the Medico-Chirurgical College faculty have been duly elected members of the faculty of under-

graduate medicine in the University of Pennsylvania: Dr. Joseph McFarland, professor of pathology; Dr. John C. Heisler, professor of anatomy; George H. Meeker, Sc.D., LL.D., professor of chemistry; Dr. Horatio C. Wood, Jr., professor of pharmacology and therapeutics, and Dr. Seneca Egbert, professor of hygiene.

DR. D. D. LEIB, instructor in mathematics at the Sheffield Scientific School, Yale University, has been appointed assistant professor of mathematics and physics at the Connecticut College for Women.

DR. V. H. YOUNG, formerly of the botany department of the University of Wisconsin, has been appointed assistant professor of botany in the State University of Iowa. He takes charge of the work in plant physiology and mycology.

DR. EUGENE P. WIGHTMAN has been appointed professor of chemistry at Richmond College to succeed Professor Eugene C. Bingham. Dr. Garnett Ryland, who was acting professor of chemistry at Richmond College last year, has returned to Georgetown College, Georgetown, Ky., after a year's leave of absence.

DISCUSSION AND CORRESPONDENCE

SCIENTIFIC APPOINTMENTS UNDER THE GOVERNMENT

TO THE EDITOR OF SCIENCE: Discussion of the President's scientific appointments may tend perceptibly toward politics, which is to be regretted in a scientific journal. Nevertheless I am in entire accord with the views of your correspondent "R" in last week's number, with the exception of two lines, which I take leave to criticize. No doubt the Coast and Geodetic Survey is one of the most important of our scientific bureaus, and one of which we can be most proud. The men at the head of it, as described in his most interesting article in your issue of July 14 by Dr. T. C. Mendenhall (not excluding himself, as he modestly does), form a very distinguished company, and we all wish that the quality may be kept up. I at least wish that the President had seen fit to appoint a superintendent whose name could be found in "Who's Who in America." Nevertheless I am informed by those competent to know that the present superintendent is a very efficient head, and we know that many of the scientific bureaus have been at times under the direction of non-scientific persons who have succeeded admirably as administrators. Several of them are now under the direction of men who have not received the blue ribbon of election to the National Academy of Sciences, although some of their subordinates have done so. Even the Coast Survey was once under a chief clerk from another department. Personally I should be glad to see a geodesist at the head of the survey, which has, if I mistake not, never been the case. Even Dr. Mendenhall does not mention that one of the things that made the Coast and Geodetic Survey most famous in Europe was the remarkable work of Dr. Hayford in connection with the subject of isostasy, so that it appears that we have geodesists in this country, as well as hydrographers.

Personally it is no more repugnant to me to have a scientific bureau headed by a non-scientist than to have a university under the presidency of a person who is not a distinguished scholar, a contingency that is not unknown. Sometimes this works very well, as in the case of the late Seth Low, who converted Columbia from a provincial college into a great university. To be sure it is whispered that the power behind the throne was his present successor, but the case is a noteworthy one. Believing, as I do, that nothing is of more importance than learning, and in learning, than science, I do not wish to minimize the importance of the selection of suitable heads of learned and scientific institutions.

I come now to the matter which prompted the writing of this communication, and I take the liberty of being somewhat personal. I wish to protest against the characterization of "the recently organized and mobilized aggregation of assorted geniuses from which the President and the country at large are expecting so much." As a member of the Naval Consulting Board I am getting very tired of such sneers, and do not expect them from my scientific colleagues. I was named for that board by

the president of a society which I am proud to represent, and my colleagues, with two exceptions, were named in a similar manner. Can your anonymous correspondent suggest a better way to select members of such a board? I was not altogether pleased with the list of societies selected, and did not hesitate to say so. But I did not for that reason refuse to serve. None of the members of this board claims to be a genius, assorted or otherwise. I do not discuss the question whether Mr. Edison is the most wonderful man the country has ever produced. I know he invented the phonograph and the incandescent lamp, which is enough to have made him famous, even if he had then stood pat, like some others. But I know that he is a fertile and tireless worker, and I am glad to serve with him. During the past year I have attended nine or ten meetings of the board, at an expense to myself of over five per cent. of a year's salary as a professor, and at a still greater sacrifice of time, which, like the money, I can ill afford. But I have thought the sacrifice justified if I could be of some small use to the country at large. I have worked occasionally before for the United States government, and I do not expect pay—thanks it is not possible to get—but I do not expect to incur jibes from fellow-scientists. This is an age of cooperation, and I believe science is at the dawn of a great epoch. We all need to pull together. Under the circumstances I accordingly feel justified in calling upon "R" for an apology, disclaimer or disavowal—the word is unimportant—either in print, under his anonymity, which I do not ask him to break, or in private over his own name, which will be treated confidentially.

In case I have made a mistake, and the National Research Council is intended, the apology should be addressed to Dr. George E. Hale, but the principle is the same.

Arthur Gordon Webster

October 23, 1916

PREPARATION FOR MEDICINE

During the past two years I have become convinced that there is a very typical course of college study through which prospective medical students are almost invariably passed. This conviction is based upon personal experience, recent enough to be very vivid, and upon conversations with many medical students.

Assuming that a man has selected his medical school, it is a very simple matter for his adviser to pick up a medical school catalogue and indicate that so much physics, so much chemistry, so much biology and such and such experience in French and German will be required in order for the student to enter the chosen school. These requirements can usually be met in two years of college work. Whether or not a college degree is necessary, the fact remains that the majority of the men in our best schools hold such degrees, and have therefore had at their disposal two extra training years. It is with these two years that I am concerned, for if they have been properly administered they can be of vast value, and almost always they are completely misdirected. A typical premedical student usually takes a year of physics, two years of inorganic chemistry, a course in organic chemistry with very deficient laboratory work, and finally a year of biology. These courses, as a rule, more than fulfil the requirements for admission to the selected medical school, and the work as arranged occupies about two and a half years of the college course. It is taken with the usual classical subjects leading to an A.B. degree. The remaining year and a half are carefully directed toward medicine by filling them with biology!

Those of us who have recollections of our college ideas of medical study will agree that there was a mysterious omnipresent picture of human dissection which occupied the entire foreground of our conception, and behind it, rather remote, a surgical background which we might some day reach. Elementary biology with its varied dissections of lower forms fitted the picture beautifully, as did histology, embryology and finally text-book courses in human anatomy and physiology. The prospective medical student finds such courses very pleasant. They are not difficult. He works much harder upon them than upon his

other studies and his success confirms him in his belief that medicine is his proper career. I know that courses in experimental biology and plant physiology are offered, which demand the immediate use and observation of physico-chemical facts. It might be maintained that such work is very direct and valuable training for medicine but I can not agree with such an attitude unless the courses in question are preceded by more fundamental physics, chemistry and physical chemistry than is now required for medical school admission. Experimental biological courses of this type do not, in my experience, reach many men. The majority have been concerned with what amounts to elementary comparative anatomy and histology, work which meets the needs neither of medicine nor of the medical school and which, though it has an educational value of high order, does not lead to the definite scientific specialization which modern medicine demands. A medical student of to-day must have a larger understanding of physics, of chemistry, and of mathematics than is pictured in the admission requirements of the school catalogues.

It is interesting to many who have had a close view of medical education and who have observed the direction of medical school development since the four-year course became general, to follow the gradual absorption of hours which had been given to different branches of anatomy, by physiological chemistry, physiology and pharmacology. The day when anatomy was the only real laboratory study is long past, and it is perhaps not an extreme view to hold that gross morbid anatomy —dissection—will be still further cut in many schools during the next ten years.

While this fact is part of the ordinary observation of all who have a historical view of the gradual stuffing and squeezing of the medical course, it has evidently not become a possession of the average college adviser who directs the student to the very door of medicine. He has a keen recollection of the struggles of his own contemporaries as they plunged along through a solid old Scotch course in gross anatomy and he thinks that every medical student must prepare for the same fate. It is true that a thorough course in comparative anatomy together with such desultory work in human anatomy as college courses offer, and, indeed, all biological studies, may make a man somewhat more efficient in his medical anatomical course. But the trouble is that the medical schedules have changed and anatomy now takes at best a quarter instead of almost the entire working laboratory time. The student prepared as I have outlined, and it is the usual preparation, finds and readily acknowledges that he has taken the correct path to equip himself for a career in anatomy if he wishes to specialize in this subject, but he finds too that he has been thoroughly cursed by wasted hours if he heads out into the many other fields which make up medicine.

I may seem to have indicated a belief that human physiology and human anatomy have no place in the college course, but this is not my intention. There can be no doubt that the more widely these subjects are taught the better. Let them be emphasized increasingly for all who are not to study medicine. The prospective medical student, however, must lay his lines in harder places.

In my experience there are not many men, who at the end of their first two medical school years, look upon anatomy as their most difficult course. True, it may have required more hours of study than any other subject, but this was due rather to bulkiness than to the character of the work. Just as in college the ordinary man regards biology as easier than physics, so in the medical school, the average student finds the purely observational task which anatomy represents far easier than physiology or physiological chemistry. Certainly with the steady encroachment of physico-chemical material it is only a matter of a very short time when this statement will be true with even greater emphasis than it is to-day. There is only one line of safety, then, for the man who plans to take medicine. He must prepare on the side of physics and chemistry, taking as much of these two subjects as his college course will permit. He will naturally take enough mathematics to keep

abreast of his progress in physics. It is by these three staunch aids alone that the trio of physiology, physiological chemistry and pharmacology may be successfully faced.

It may be objected that the man who sacrifices his biological training—and by this I mean takes no more than the present minimum required by the medical school of his selection—while he may find himself in better shape for physiology, etc., will not be better off in his medicine and surgery later on. By the same voice we shall hear that *general practise* does not need this scientific underpinning. I do not know what the training of that vague person, the "practical family doctor," should be, but I do know that he will make poor shift to graduate well from the modern medical school unless he heed his early training, and poorer shift still to keep up with current medical literature later on if he has failed to appreciate the direction in which medicine is growing.

The constant establishment of surgical and medical research laboratories with the consequent injection of scientific methods into the practical branches, is a matter of general comment, and emphasizes the large influences which are shaping medicine into a science. It is possible that most men who advise college premedical students are somewhat aware of the facts which I have tried to bring out in this paper, but feel strongly that such early and emphatic specialization as has been advocated may have a narrowing influence. If this be their attitude they are not consistent in permitting wide excursion into anatomical biology with the idea of better equipment for medicine later on, and it is against the futility of such a course that I protest.

It is often hard to point out to students the utility of subjects, essentially somewhat abstract, in their relation to medicine. This is especially true when one is confronted by the fact that medical school catalogues do not advise the prospective student to fulfil the given requirements, and then if possible to extend his course in the directions I have indicated. Yet there is no doubt that the man well grounded in these fundamental subjects, which become very inaccessible after the medical school is once entered, possesses an advantage over his less fortunate fellows which can be turned to most vivid and permanent account.

Cecil K. Drinker
Department of Physiology,
Harvard Medical School

THE AURORAL DISPLAY OF AUGUST 26

To the Editor of Science: The notes by Dr. Nutting and others in Science on the Aurora of August 26 have been read with much interest by the writer. None of these, however, mentions the appearance of this phenomenon from a point as far south as Washington. On the evening in question, I was sitting on the front porch (facing north) of my residence here. It had been quite a warm day and in the north was a heavy bank of clouds in which lightning had been playing all through the twilight and early evening; the sunset glow seemed to be unduly prolonged back of this bank of clouds. My attention was first called to what I took to be a small, faintly luminous cloud, about the shape of a mirror image of the map of Nevada, which covered a portion of the constellation of the Great Dipper. The length of this supposed cloud was about equal to that of the handle of the Dipper, with the longer axis at right angles to the handle. After persisting for some time this little patch moved away rather rapidly to the west and disappeared, only to reappear in its original position after the lapse of several minutes. Meanwhile, the seemingly prolonged sunset glow above the bank of clouds in the north had become a fringe of pale steady light, apparently extending out over the edge of the cloud a considerable distance. While the small patch of light over the Dipper soon disappeared again, the glow back of the cloud bank persisted for a long time. No distinct color was observed, the light being a uniform faint white; no streaming or other movement was observed, except that of the small patch of light already described.

F. Alex. McDermott
Washington, D. C.,
October 26

THE auroral display of August 26 described by Professor Nutting and others in recent numbers of SCIENCE, I observed from Lucasville, 10 miles north of the Ohio River in Scioto County, Ohio. This is in practically the same latitude as Washington and much farther south than the observations recorded to date of writing. It took the form of a bright, white, uniform illumination of the entire northern heavens, which extended in decreasing intensity almost to the zenith. Although watched intermittently for about an hour between 8.30 and 9.30 o'clock, no color bands, streamers, curtains, moving light waves, pulsations or other phenomena were observed, nor was any tendency to increase or diminish in brightness detected.

The same display was witnessed by many lake-shore campers at Cleveland, and was noted by Cleveland papers the next day. The diffused character of the light over the lake and its greenish color were particularly noted.

J. E. HYDE
WESTERN RESERVE UNIVERSITY

TO THE EDITOR OF SCIENCE: In connection with Professor Nutting's vivid account in a recent number of SCIENCE (p. 496) of a remarkable auroral display witnessed by him at Lake Douglas, Michigan, it is perhaps of interest to record that the same or a similar display was observed that identical evening in a region as remote as the Glacier National Park, Montana.

At about 10: P.M., August 26, while Mr. E. H. Dole and myself were returning from the Many Glacier Hotel to the nearby Teepee Camp on Lake McDermott, our attention was attracted by a peculiar bright glow quite low on the horizon in the eastern sky, as though from the lights of a great city. We were much puzzled by it until we had emerged far enough from the disturbing glare of the electric lights to discover that a similar, though weaker glow was in the west, and indeed that an evanescent shimmering arch of light extended not only clear above us, but well past the zenith into the southern sector of the heavens. Unfortunately our view to the north was effectually obstructed by the gloomy bulk of Altyn Peak and the canyon wall, but by this time the auroral nature of the phenomena was evident to us. While too shut in by the narrow valley to secure the full enjoyment of the display which so enthralled Professor Nutting, that which we saw seemed sufficiently remarkable. The light extended over the sky and seemingly diffused through the whole upper atmosphere in so general a glow that here also its real brilliance was difficult to appreciate. Quavering streams of light—an everchanging sheen, sometimes brighter here, sometimes brighter there—never uniform—no simile could be more delightfully suggestive than Professor Nutting's allusion to the photogenic play of the meridional bands of Ctenophores as seen in darkened water. The same comparison forced itself into my own mind at the time.

S. STILLMAN BERRY
REDLANDS, CALIFORNIA,
October 19

TO THE EDITOR OF SCIENCE: I was much interested to read in the current number (October 20) of SCIENCE the records of places at which the auroral display of August 26, 1916, was seen. All five of the notes in this issue report observation of the display at points to the east and northeast of the locality reported by Professor Nutting in SCIENCE of October 6.

Following the suggestion of Professor Baker, I wish to record having observed the same phenomenon during the same evening at Amery, Wis., fifty miles northeast of St. Paul, Minn. The same remarkable features so well described by several writers were in evidence—the ever-changing, ebbing and swelling pulsations and the shimmering streamers of light, fading and intensifying at the same time in different parts of the heavens—but no marked exhibition of color so far as noticed. The center of the display was near the zenith and practically the whole sky was occupied except at times a rather narrow indefinite band or strip in the south.

Mr. Paul B. Sears, also a member of this department, informs me that on the same night he observed the display at Madison in northeastern Nebraska. The phenomenon exhibited

practically the same features in this locality as in Wisconsin and Michigan.

This information may be of interest as extending considerably the recorded area over which the display was visible.

Wilmer G. Stover
Ohio State University,
October 24

To the Editor of Science: I have been greatly interested in the descriptions of the auroral display of August 26, and would like to add a word to what you have already published. I observed the phenomenon at Ephraim, in Door County, Wisconsin, between ten o'clock and midnight; other observers at the same place reported to me that it lasted until long after midnight. The description of the display as given by your contributors corresponds in the main with my own observation, but with one difference: I saw two distinct color regions in addition to the white pulsation described by all the others. At the zenith the color was white, but in the east there was a region that changed several times from pure white to a brilliant rose color, while in the north there were streamers of delicate green. The universal, shadowless illumination was very remarkable, as was also the display in the southern sky, where the streamers reached almost to the horizon.

John C. Hessler
The James Millikin University
October 21

To the Editor of Science: I have been interested in the reports of the auroral display of last August, by Professor Nutting and others. The aurora was seen with all the brilliancy and variation of colors described by Professor Nutting, at Lake Minnetonka, near Minneapolis, Minn., on the 26th of August.

We were out in a boat, and, when well out in the lake, there appeared what at first seemed to be the glow thrown on the eastern sky by a fire. The light was not as red as that produced by a fire, and there were no clouds in the sky where the light first appeared. As we watched it, it soon became evident that the light was not from a fire but that of an aurora. It appeared a little to the north of east down near the horizon, gradually rising and forming an arch across the northern sky a little higher than is usual for auroras in Minnesota. Then another band appeared below the first and lower down in the north. These bands were not as definite as in most of the auroras that I have seen in Minnesota, nor did they show the vertical bands of light, but the diffuse light seemed concentrated in these two regions.

Then more rapidly the light mounted upwards and as it reached almost to the zenith there suddenly was formed what seemed a vortex of scintillating iridescent light. Pausing here for a moment the light continued to extend on to the southern half of the sky until it reached nearly half way to the southern horizon, or until nearly all of the sky was lighted with this constantly changing light in bands, and areas.

The rapidity of change both in distribution as well as in color of the light was fully as marked as that described by Professor Nutting.

We watched the display until ten o'clock, and others said that it was even more brilliant later.

H. B. Latimer
University of Nebraska,
October 23

To the Editor of Science: Among the reports on the unusual auroral display of August 26, I see none from farther west than Michigan. It might be of interest to readers of Science to know that this display was visible in all its splendor at Winton, Minnesota, north of Duluth, and was very much as described by Professor Nutting, except for the lack of color which he describes.

R. R. Hudelson
University of Missouri,
October 26

To the Editor of Science: Unfortunately, I was not further west than Brainerd, Minnesota, on August 26, but that is in the same latitude and five hundred miles west of Lake Douglas, in Michigan, where Professor Nutting saw the auroral display. These displays are common occurrences in the wintry months in this locality, often being brilliant, but in

recent years none compared with this one. Together several of us observed it until almost twelve o'clock, but its greatest brilliancy and intensity was seen before eleven. Among the striking things was the rapidity of the movements, the brilliancy at the zenith, and the distance to which the bands of light extended into the south. It seemed as though the light originated near us, so bright was the display at the horizon in the north. The color was variable from light-green to light-yellow and gray.

CARL ZAPFFE

BRAINERD, MINN.,
October 25

TO THE EDITOR OF SCIENCE: Since the accounts of the aurora of August 26 in SCIENCE for October 6 and 20 covered only an area from Michigan eastward, it will be of interest to know that it was observed at least as far west as the Front Range of the Rockies in northern Montana. We were camped at the time a few miles east of the old postoffice of Saypo or west of Chateau in Teton County, some eight miles east of the mountain front. The phenomena here were very much like those described by others. I give them from memory.

As the brilliant, yellow, diffused light of sunset faded in an absolutely cloudless sky, an arch of white light became visible extending across the sky from east to west, perhaps 60° from the northern horizon. North of this were three or four broad vertical bands of white, the lower ends somewhat fringed as they are so often shown in illustrations, but I noticed no streamer-like motion. The arch slowly moved southward, mounting in the sky. Between nine and nearly eleven I saw nothing further of the aurora, but when we looked at it again, shortly before eleven the east and west arch was only some 20°–30° above the south horizon and all the rest of the sky to the north of it was aflame with white lights, which, as I remember it, waved and flickered irregularly, but incessantly from all sides towards the zenith. A few minutes later all traces of the auroral glow seemed to have disappeared.

Though I saw only white lights myself, some people whom we spoke to next day mentioned a pink glow.

MARCUS I. GOLDMAN

U. S. GEOLOGICAL SURVEY,
WASHINGTON, D. C.,
October 31

TO THE EDITOR OF SCIENCE: It is interesting to note that the auroral display of August 26 was visible in southwestern Montana. Owing to the prevailing atmospheric conditions it appeared to be of a different character there. The writer and a companion, being engaged in geologic work in the Beartooth Mountains under the direction of the University of Chicago, were at that time camped just below the rim of one of the high plateaus on the northeastern side of the range, at an elevation of about 9,500 feet. The most violent thunderstorm of the season had swept over the plateau the previous evening. In the morning great banks of fog rolled up from the canyons, completely hiding the plateau for the greater part of the day. Toward evening the fog lifted slightly, and about nine o'clock a luminous rosy light was noticed in the northeast. It was a steady glow that spread from the horizon, which was quite high, far up in the sky. No streaks or shafts of light of any sort were seen during the half hour that the light was observed.

A feature of the occurrence as viewed in that locality, which has not been reported elsewhere, was the repetition of the phenomenon on the following evening, but on a much smaller scale. From the bottom of the canyon a faint glow was seen over the rim of the plateau, but it was observed for a short time only.

ARTHUR BEVAN

UNIVERSITY OF CHICAGO,
October 30

TO THE EDITOR OF SCIENCE: The auroral display of August 26, first described in your columns by Professor C. C. Nutting, was also observed from the Columbia River Gorge, forty-five miles east of Portland. I was a member of a party of geology students from the University of Chicago and on the night of the display our camp was located on the north side of the river at Collins, Washing-

ton. The light first appeared from the northeast in the form of a brilliant belt of pearly white, the rays of which seemed to converge toward a center somewhat below the horizon. It became so intense and the direction of the belt shifted in such a fashion that some members of the party at once thought it was the headlight of a train approaching around a curve. In a very few minutes the display changed to a brilliant array of streamers with intermediate belts of diffused light, all of which seemed to diverge from a common center. At this stage it resembled very much the corona type of aurora, with the exception that the streamers reached almost to the zenith. The intensity of the light and the position of the streamers were constantly changing, but the source from which they seemed to diverge remained fixed for almost half an hour. Finally this aspect of the display vanished, and there appeared a broad band of diffused light that began swinging across the heavens from the original position in the northeast to an east-west position and extending from the eastern horizon through the zenith almost to the western horizon where it faded out. It remained fixed in this position for at least fifteen minutes, during which time it gradually narrowed and grew in intensity until its width might well be compared to that of a rainbow and its brilliance became more striking than ever. At length it began to fade away and finally disappeared. At no time did we observe the coloring described by Professor Nutting. The phenomenon first appeared between nine and ten o'clock Pacific Standard time, which was not very far in absolute time from that of Professor Nutting's observation in northern Michigan.

W. L. Foster

University of Chicago,
November 2

On August 26 I was in camp with Dr. Walcott at Hector, a station on the Canadian Pacific Railway, practically on the divide of the Rocky Mountains in British Columbia.

The view northward is limited by a mountain ridge two thousand feet or more above the camp. Mountain masses are not far distant to the southeast and southwest, but to the east, south and west the view is quite extensive.

At 8:40 P.M. (two hours slower than eastern time) a faint "curtain" of light appeared in the northeast, well above the mountain. Immediately afterward this was extended by waving columns of light to the eastward and westward: then a veritable "glory" appeared spreading across the northern hemisphere. Long beams of light as though from huge searchlights flamed across the sky, curtains and bands formed in swaying folds. A little later, about nine o'clock, the whole heavens were included, with rays extending from the zenith to the horizon (as limited by the topographic features).

There seemed to be a shower of light surrounding us, which gradually faded. Up to this time the light was white or very pale green in places. Immediately followed a gorgeous display of colored lights, reds, greens, blues, more nearly in the north. In the whole display the motion of light was from east to west.

R. H. Chapman

Washington, D. C.

To the Editor of Science: It may interest the readers of Science to know that the auroral display of August 26, which has already been extensively commented upon in these columns, was visible in the Selkirk Mountains in British Columbia, upwards of three thousand miles west of the extreme easternmost locality in Nova Scotia reported by Professor Heyl. Auroral displays are not infrequent during the summer months in the Selkirk Range, but the one in question was the most brilliant, and otherwise the most remarkable, of all that I have seen in this region during an experience covering the greater part of six summers. It may, or may not, be of significance that it came shortly before a period of twelve consecutive rainy days, during which thunderstorms—usually relatively rare in the Selkirks—were both numerous and violent, and severe hail-storms also occurred

over a wide area. Miners in this part of British Columbia believe that in the winter a particularly brilliant display of the aurora is likely to be followed by a heavy fall of snow, but I am unable to determine how far the actual records bear out this belief.

M. H. JACOBS
UNIVERSITY OF PENNSYLVANIA

SCIENTIFIC BOOKS

The Life of Inland Waters. An elementary text-book of fresh-water biology for American students. By JAMES G. NEEDHAM, Professor of Limnology in Cornell University, and J. T. LLOYD, Instructor in Limnology in Cornell University. Octavo of 438 pages with 244 illustrations. 1916. The Comstock Publishing Company, Ithaca, New York.

Needham and Lloyd have produced a very good and very useful book. It is well planned, well executed and well illustrated. It deals with the life of fresh water—chiefly the microscopic forms and the insects—from the point of view of environment and mutual adjustment. It is, therefore, not a handbook for identifying forms, nor is it a treatise on limnology and its methods, or even on fresh-water biology. It is not a "popular" book, to be read with full intelligence and interest by a person ignorant of biology and of fresh-water life in particular. It is rather a book to accompany the study of fresh-water biology in laboratory and in the field. It gives the general points of view, the grouping and correlation of facts, which such a student needs if he is not to become entangled in a hopeless web of details. This it does in moderate compass and with sufficient detail to make the principles clear, definite, and, therefore, useful to the student.

The subject is handled under four main heads: (1) the nature and the types of aquatic environment; (2) aquatic plants and animals; (3) adjustment of plants and animals to conditions of aquatic life and to each other in aquatic societies; (4) inland water culture. The reviewer finds the fourth head the least interesting, though not the least important from a practical point of view. Less has been done and, therefore, there is less to be said about this matter as yet. The third head (Chapters V. and VI.) shows the book at its best. The interrelation of plants and animals and the adjustment of both to environment are here discussed. Chapter V., for instance, treats first of individual adjustment to aquatic life, whether in open water or on the bottom. Methods of floating, swimming, etc., are described for the open-water forms, and methods of burrowing, shelter building, motion on and through the mud, etc., for the bottom forms. Adjustment of the life cycle to seasonal changes in the aquatic environment is then considered, involving such matters as statoblasts and winter eggs. Mutual adjustment is briefly treated and illustrated by the insectivorous marsh plants and by the larval habits of mussels. Chapter VI. deals, first, with limnetic societies, primarily divided into those of open water and those of the shores. The former includes the plankton (persistently spelled "plancton" by the authors—doubtless with reformers' intentions); the latter set includes the shallow-water societies passing into those of ponds, pools and marshes. The chapter concludes with an account of the lotic societies, or those of streams. All of these forms of association are well described and especially well illustrated.

Of course any specialist will see places where he would have written the book differently, and places where he would have enlarged or reduced the space given by the authors. One must regret that the fascinating and valuable subject of mutual adjustment is so briefly treated. The emphasis on insects will seem somewhat disproportionately large to students of other groups. It seems to the present reviewer that the account of physical conditions of life in lakes has not the vigor of the ecological chapters. Here and there the subject is somewhat fumbled, as in the treatment of lake temperatures. The summer temperature conditions of Cayuga Lake, shown in

Fig. 4, are very different from those shown in Fig. 5. The latter figure plainly does not come from observations in the open lake. This can not fall to 4° by December 1; nor can the surface maintain a temperature of nearly 30° in July. The discussion of the thermocline shows that the authors' interests are primarily elsewhere than with temperatures.

But such matters do not detract from the general value of the book, both for students and as a contribution to limnology.

A word must be said of the illustrations which, in general, are extraordinarily good. Sometimes photography is pushed too far. Not a few photographs of insects, etc., are from objects so dark that they do not show necessary detail. In such cases a drawing would do much better service. But a great many of the photographs, such as Fig. 61—duck-meat—and Fig. 207 really illustrate the subject and tell the student in the study what he ought to see in the field.

E. A. Birge

Individuality in Organisms. By Charles Manning Child, Professor of Zoology in the University of Chicago. The University of Chicago Press, 1915. Pp. 213. $1.25 net.

What is the nature of the unity and order which characterize the organic individual? Upon the basis of fifteen years of experimental and analytical investigation Professor Child in his recent book on "Individuality in Organisms" attempts to give an answer to this important problem.

In the first chapter of the book the writer makes clear that he is dealing with the problem of physiological individuality exclusively without metaphysical assumptions. Current hypotheses of the individual are found either to ignore the problem of the unity and order within the organism, or they carry with them vitalistic implications. His criticism of these hypotheses in chapter two forms one of the most readable portions of the book.

In place of current "corpuscular" theories of the individual which postulate "a mysterious, self-determined organization in the protoplasm, cell or cell-mass," Professor Child would substitute a dynamic conception of the individual. Physiological unity and order in his opinion are to be interpreted not in terms of a hypothetical organization and the transportation of chemical substances within the organism, but in terms of differences in the rate of reaction and of transmitted change. The basis of individuality lies in "spatial quantitative differences in the action of external factors on protoplasm." He finds experimentally that the head of the animal and the growing tip of the plant are centers of more active metabolism while posteriorly or basally processes are less intense. This evidence has led him to his doctrine of metabolic gradients, proof of the existence of which is advanced in chapter three.

Concluding that "the organic individual is fundamentally a dynamic relation of dominance and subordination, associated with and resulting from the establishment of a metabolic gradient or gradients," Dr. Child in subsequent chapters presents evidence of dominance within the organism and discusses the limitations of its range. Dominance in the individual is determined primarily, not by means of the transportation of chemical substances from one organ to another, but through the transmission of impulses just as in the nervous system. Subsequent to organic differentiation in ontogeny, however, integration of the organism may be partly effected through the transportation of chemical substances.

The bearings of the hypothesis upon the problems of differentiation, reproduction, heredity and evolution are suggested and briefly discussed in the concluding chapter of the book.

The claims of the author for his hypothesis are modest. It is certainly not too much to say that it has already proved its value as "a basis for the synthesis and ordering of many facts in various fields which heretofore have seemed to have little or nothing in common" and that it has brought "certain aspects of biology within hailing distance of physico-chemical conceptions." Adverse criticism has been largely forestalled by the objections which Dr. Child has himself raised and an-

swered, and by his resourcefulness in experimental verification.

The theory seems less satisfactory in its application to the phenomena of gametic reproduction than to the processes of regeneration. Pushed to its logical extreme in its application to ontogenesis the process of individuation postulated by Child appears to be one of complete epigenesis and the organization which develops to be due exclusively to external factors. In order to meet the insuperable difficulties which would be raised against a consistent theory of epigenesis, Dr. Child assumes that as a result of the influence of external conditions through many generations and through the inheritance of the acquired modifications, reproductive cells or cell-masses have come to possess "a fundamental reaction system" which constitutes a basis of preformation and conditions their development and their reaction to external stimuli. In this way it is possible to understand why under similar external conditions the ontogenesis of different species varies so greatly. Moreover, the "fundamental reaction systems" may be further modified through their intra-individual environment.

In order to meet the difficulty of understanding how a "reaction system" involving primarily only quantitative dynamic differences determines specific qualitative differences which appear in ontogeny, Dr. Child is led to assume primary differences in the specific constitution of the protoplasm of different eggs or cell-masses. But, since "systems" suggest spatial localization and the "specific constitution of protoplasm" implies chemical differentiation, does it not seem as if the basis of individuality postulated by Dr. Child is essentially like that assumed in the hypotheses which Dr. Child repudiates? On the whole, however, Dr. Child's hypothesis of individuality appears to be the best supported and the most consistent mechanistic hypothesis which has been advanced.

As the product of the mature thought of an independent and resourceful investigator "Individuality in Organisms" will take a permanent place in biological literature.

H. V. NEAL

PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES

THE tenth number of Volume 2 of the *Proceedings of the National Academy of Sciences* contains the following articles:

Preliminary Results on the Color of Nebulæ: F. H. Seares, Mount Wilson Solar Observatory, Carnegie Institution of Washington. Photographs of a Messier 51, 94, 99 show that the nebular condensations have large negative color indices. The knots of nebulosity are bluer than the bluest of the neighboring stars. The spectral character of the outlying regions differs from that of the central nucleus. In the case of the planetary nebula N. G. C. 3242 no important differences of this sort are revealed.

The Action of Alkali in the Production of Lipolytically Active Protein: K. George Falk, Harriman Research Laboratory, Roosevelt Hospital, New York. The author discusses: Inactivation of the enzymes by acid, by alkali, by alcohols, by acetone, by salts and by heat; nature of the chemical changes involved in the inactivations; and activation of proteins by alkali.

The Excretion of Acids by Roots: A. R. Haas, Laboratory of Plant Physiology, Harvard University. The author finds that no acid other than carbonic was excreted from the roots of corn seedlings. Similar results were obtained for wheat seedlings.

Spectrographic Observations of Relative Motions in the Planetary Nebulæ: W. W. Campbell and J. H. Moore, Lick Observatory, University of California. Further observations indicating the probability of the hypothesis that the so-called ring nebulæ are in reality not ring forms, but ellipsoidal shells. Tentative conclusions are also drawn as to the probable masses of the nebulæ.

New Determinations of Permeability: S. C. Brooks, Laboratory of Plant Physiology, Harvard University. The determinations have been made by a new independent method and by improved older methods. The results agree in showing that living protoplasms are normally permeable to the salts studied, but salts of pure solutions may alter permeability, some causing an increase of permeability while

others cause a decrease, followed by an increase, of permeability. In a properly balanced solution the permeability remains normal. Cell walls may be semipermeable to an extent which renders them important in such experiments.

Point Sets and Cremona Groups. Part III.: Arthur A. Coble, Department of Mathematics, Johns Hopkins University. The group $G^2_{6,2}$ is used in the problem of determining the lines of a cubic surface. The determination differs from that of Klein.

The Interferences of Spectra both reversed and inverted: Carl Barus, Department of Physics, Brown University.

Sex Intergrades in a Species of Crustacea: Arthur M. Banta, Station for Experimental Evolution, Carnegie Institution of Washington. The author has collected a large amount of data on several species of Cladocera which is interesting because of the remarkable array of sex forms, the stock in general consisting of perhaps 40 per cent. normal males and about 8 per cent. normal females, the remainder being intergrades with *almost* every combination of sex characters.

Some Problems of Diophantine Approximation a Remarkable Trigonometrical Series: G. H. Hardy and J. E. Littlewood, Trinity College, Cambridge, England. A series is given which is never convergent or summable for any value of θ, and is accordingly not a Fourier's series. And further a function is found which does not possess a finite differential coefficient for any value of θ.

Steric Hindrance and the Existence of Odd Molecules (Free Radicals): Gilbert N. Lewis, Chemical Laboratory, University of California. It is contended that the hypothesis underlying the somewhat elusive phrase "steric hindrance" should not be introduced until phenomena are known which can not be so well explained in other ways. It is shown how the so-called free radical of organic chemistry may be explained independently of the hypothesis of steric hindrance.

Newton's Method in General Analysis: Albert A. Bennett, Department of Mathematics, Princeton University. An extension to general analyses of special algebraic work of H. B. Fine.

The Cobaltammines: William D. Harkins, R. E. Hall and W. A. Roberts, Kent Chemical Laboratory, University of Chicago. The authors have determined accurately the freezing-point lowerings caused by eight different cobaltammine salts, and have derived from the results the number of ions into which each salt dissociates. These are found to be in accordance with Werner's theory.

National Research Council: Report of the First Meeting of the Council. Reports of meetings of the Executive Committee. Organization of the Research Council (as at present constituted).

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THE AURIFEROUS GRAVELS OF THE SIERRA NEVADA

The origin and the natural distribution of the $300,000,000 of gold that has been mined from the Tertiary placer gravels of the Sierra Nevada of California is the subject of a report by Waldemar Lindgren, which has been published by the United States Geological Survey as Professional Paper 73.

The Geological Survey's studies of the Tertiary placer deposits of the California Sierra began in 1886 and were concluded about 15 years later. During this period 22 quadrangular areas were topographically mapped and 14 of these were studied in geologic detail and the results published by the survey in geologic folios. Professional Paper 73 includes the salient features of this earlier work, most of which was done by Mr. Lindgren himself. This report, thus comprehensive in geographic scope and minute in geologic detail, is believed to be the most complete and thorough description of a great placer-gold province ever published.

In the main the report is a detailed description of the entire area covered, including the gold placer gravels, but Mr. Lindgren's general account of the tremendous earth forces that built up the Sierra and of the processes

that freed the gold from its mother rock and brought about its concentration in prehistoric river channels forms altogether a most impressive description of continent building. Looking backward through inconceivably long vistas of time in which periods covering millions of years supplant the centuries by which we now compute its passage, the geologist pictures the uplift of the new-born mountain range by upward-forced great bodies of molten granite. This uplift was accompanied or closely followed by the formation of veins and seams of gold-bearing quartz, and the resulting highland was then planed down by erosion caused by rainfall and the action of streams of water.

Tracing the long course of this early history the geologist now finds that toward the end of what is known as Tertiary time—a comparatively recent geologic period—volcanic forces that had long been quiescent vigorously reasserted themselves. Flows of rhyolite, a volcanic rock, pouring from many craters, filled valleys that were covered with gold-bearing gravel, deeply burying the gold and causing the formation of new stream courses.

The geologic events thus outlined long preceded the period of human history in which these metal deposits were mined. In 1849 an army of gold seekers invaded the Sierra. They worked first along the present streams, but gradually the metal was traced to the old Tertiary river beds on the summits of the ridges and to the quartz veins, the primary source of all the gold in the Sierra Nevada. Millions of dollars in gold were produced annually up to the seventies of the last century, but the gold-mining industry has slowly diminished, until now less than $1,000,000 is produced annually, the decline being due to the prohibition of hydraulic mining and the exhaustion of the richer channels suitable for drift mining.

The total output of gold in California is estimated at $1,200,000,000 to $1,500,000,000, about one fifth of which has been derived from quartz veins, $300,000,000 from the Tertiary gravels, and the remainder from the Quaternary deposits.

SPECIAL ARTICLES

ON THE DIFFERENTIAL EFFECT OF CERTAIN CALCIUM SALTS UPON THE RATE OF GROWTH OF THE TWO SEXES OF THE DOMESTIC FOWL[1]

IN connection with an extensive series of experiments on the effect of feeding various organ substances to growing chicks, which I have been carrying out during the past summer with the aid of Mr. W. T. Pettey, two groups were given small daily doses (Ca. 0.1 gm. to 0.3 gm.) of calcium lactate ($Ca(C_3H_5O_3)_2 + 5H_2O$) and calcium lactophosphate (a mixture of calcium lactate and calcium phosphate containing about 3 per cent. of the latter), respectively. The results were consistent, striking, and in certain particulars entirely new. A complete account of them, with detailed figures, will be published as soon as the material can be prepared for the press. In the meantime I wish to call attention, in a very brief way, to the essential features of the results. The most significant finding is that while neither of these calcium salts affects in any way, in the dosage used, the rate or amount of growth *in the male chicks,* both of them, but particularly the lactophosphate, induce a very marked increase in the absolute amount of growth and a corresponding acceleration in its rate *in the female chicks.* The dosage was begun when the birds were 29 days of age and continued until they were 171 days old, after which age there is comparatively little additional growth in the domestic fowl. At the end of this 142-day period the lactophosphate females had grown so much faster than the control females that there had been eliminated 58.4 per cent. of the normal difference between the sexes in respect to body weight (secondary sexual character). In spite of the rather large probable errors the absolute differences are statistically significant. Thus we have at 171 days of age:

Lactophosphate ♀♀ mean wt. — Control ♀♀ mean wt. $= 354.6 \pm 91.9$ gm.

The difference is 3.85 times its probable error.

The reproductive organs of the females were stimulated as well as growth. The rate of

[1] Papers from the Biological Laboratory of the Maine Agricultural Experiment Station, No. 104.

egg production per unit of time in the lactophosphate females is nearly 5 times as great as in the controls.

A further point of interest is that if a very small dose of corpus luteum substance[2] be administered to the birds each day along with the calcium lactophosphate the stimulating effect of the latter upon the growth of the females is completely inhibited.

It has been known that the internal secretions of certain organs might have a different effect upon the growth of males and females, and indeed in the present series of experiments we have seen such a differential effect following the feeding of several different gland substances. It is another thing, however, to find inorganic salts exercising such a differential effect. It furnishes one more piece of evidence of the deep-seated biochemical differences which underlie sex differences, and at the same time is in line with the medical evidence as to the great importance of calcium in the physiology of the reproductive organs of the female.

Raymond Pearl

October 31, 1916

THE PRESENT STATUS OF THE DOLOMITE PROBLEM[1]

The problem of the origin of the dolomites and dolomitic limestones has long occupied the minds of geologists and many theories have been advanced for their formation. But no one of these has been universally accepted. The chief theories which have been proposed are briefly as follows: First, the alteration theories which assume that dolomites have been formed by the partial replacement of limestones by magnesia either (1) before they emerged from the sea, through the agency of sea-water, or (2) subsequent to their emergence through the agency of ground-water. Second, the primary deposition theories which maintain that the dolomites were originally deposited in the form that they now appear, (1) by chemical precipitation from the sea, or (2) by the deposition of clastic grains of dolomite derived from the disintegration of older dolomitic limestones. Third, the leaching theories which are based on the well-known fact that during the weathering of a dolomitic limestone the lime is removed more rapidly than the magnesia, thereby causing an enrichment of the latter constituent. This leaching is supposed to take place either (1) through the agency of sea-water prior to emergence, or (2) through the agency of atmospheric water after the limestone has become a part of the land.

The marine alteration theory is by far the most widely held to-day, but the chemical precipitation theory has many champions.

The writer was led to suspect several years ago, that a careful field study of dolomitic formations would throw some light upon their origin and through the aid of the Iowa Geological Survey and an appropriation from the Esther Herrman Research Fund of the New York Academy of Sciences he has been able to examine nearly all of the important dolomites of the Mississippi Valley and the eastern United States.

These studies have furnished irrefutable evidence that the majority of the dolomites examined have resulted from the alteration of limestone. The following facts support this contention: (1) the lateral gradation of beds of dolomite into limestone, sometimes very abruptly; (2) the mottling of limestones on the border of dolomite masses by irregular patches of dolomite; (3) the existence of remnants of unaltered limestone in dolomite, and of nests of dolomite in limestone; (4) the irregular boundaries between certain beds of limestone and dolomite; (5) the presence of altered oolites in some dolomites; (6) the protective effect of shale beds; and (7) the partial obliteration of original structures and textures in many dolomites and dolomitic limestones.

Concerning the conditions under which the dolomitization took place there are many reasons for believing that the more extensive dolomites have all been formed beneath the sea prior to or contemporaneously with recrystallization and that the dolomitiza-

[2] A material which I have earlier shown (*Jour. Biol. Chem.*, Vol. XXIV., pp. 123–135, 1916) to have a retarding or inhibiting effect upon the growth of the chick.

[1] A more complete report on the origin of dolomite will appear in Vol. XXV. of the Iowa Geological Survey, which is now in press.

tion produced by ground-water is only local and very imperfect. Some of the features which lend weight to this view are as follows: (1) Recent dolomitized coral reefs are known to have been formed by the reaction of the magnesia of sea-water with the limestone. (2) The dolomite areas of mottled limestones are believed to have undergone recrystallization at the same time as the associated limestone areas, as suggested by the occasional development of zonal growths of calcite and dolomite. (3) In imperfectly altered limestones the dolomite is seen to follow original lines of weakness rather than secondary structures, such as joints or fractures. (4) In most cases of mottling the dolomitization appears to have progressed uniformly as we should expect it to do in an unrecrystallized rock, rather than to have progressed by forming veinlets and stringers in the early stages. (5) The existence of perfect rhombs of dolomite in many imperfectly altered limestones suggests that the latter had not yet solidified when the dolomite rhombs were formed. (6) The widespread extent and nearly uniform composition of many dolomites indicates that they must have been formed by an agent capable of operating uniformly over wide areas. (7) An adequate source of magnesia for transforming extensive limestone formations into dolomite is found only in the sea, which contains many times as much of the constituent as ordinary ground-water. (8) Many dolomites are directly and regularly overlain by pure limestone formations or by thick shale beds, proving that they must have been formed before these overlying beds were deposited and that descending ground-water has not been influential in their production.

The evidence of dolomitization beneath the sea then must be considered as positive, but the controlling factors of the process are very imperfectly understood, due chiefly to the lack of careful study of the phenomenon in the modern seas. A thorough investigation of the conditions which favor the transformation in the sea to-day would be invaluable in interpreting the history of the ancient dolomites. It is believed that very important data bearing on the problem could be obtained from a more careful study of the coral islands of the Southern Pacific.

As to whether dolomitization takes place in concentrated seas or not there has been considerable disagreement. Until recently the tendency has been to follow Dana, who believed that dolomitized portions of recent coral reefs were formed in concentrated lagoons and assumed that the ancient dolomites must have been formed under similar conditions, but Skeats pointed out in 1905[2] that the outer parts of certain fringing reefs of the South Sea Islands, which face the open ocean, are occasionally dolomitized and that the dolomitization of coral reefs is not confined to the lagoons; and Philippi[3] soon after presented evidence of recent dolomitization in the open sea. Still more recently, Blackwelder[4] has given it as his opinion that the Bighorn dolomite has resulted from the progressive alteration of limestone during deposition, the concentration of the magnesia being not more than two or three times as great as in the present ocean, since more than this amount would have been unfavorable to the life processes of the time. There are many commendable points to this theory of progressive dolomitization at low concentrations, but if dolomitization can go on under these conditions, why are not all of our limestones dolomitic? In answer to this query it might be said that the alteration takes place under unusual circumstances, possibly through the agency of certain bacteria which are not always present when limestone is deposited.[5] But much of the field evidence speaks against progressive dolomitization. The wavy boundaries sometimes exhibited between the dolomitic and non-dolomitic portions of formations; the lateral gradation of beds of dolomite into limestone; pseudo-interstratification effects of

[2] *Quart. Jour. Geol. Soc. London*, Vol. LXI., p. 97, 1905.

[3] *Neues Jahrb.*, Festband, Vol. I., 1907, p. 397.

[4] *Bull. Geol. Soc. America*, Vol. XXIV., p. 607, 1913.

[5] Both Nadson and Walther have suggested the possible influence of bacteria in dolomitization. See "Gesichte der Erde und des Lebens," p. 90.

dolomite and limestone; the presence of imperfectly dolomitized oolite beds in dolomites; the occurrence of mottled limestones grading gradually into dolomite, and many other features can only be accounted for by assuming that dolomitization took place after all of the beds involved were deposited, or at least in the closing stages of their deposition. When, however, a pure limestone member succeeds a dolomite member, known to be an alteration product, conformably, the contact line being regular and continuous over wide areas, it can not be assumed that this relationship has resulted from the alteration of the lower bed after both beds were deposited. The "Lower Buff beds" of northeastern Iowa, which consist of dolomite with occasional minute limestone remnants, are abruptly followed by the pure limestone of the "Lower Blue beds" over hundreds of square miles, the transition from one into the other taking place through only a few inches of imperfectly dolomitized limestone.

Moreover, the tendency of some limestones to be more highly dolomitic in their lower portions and to become progressively less dolomitic upwards, must also be regarded as lending support to the theory of progressive dolomitization. Orton and Peppel[6] state that the Delaware and Columbus limestones of Ohio are more dolomitic in their lower than in their upper portions.

But even if it should be positively shown that dolomitization can go on at low concentrations, all must agree that it would proceed not only much more rapidly, but also more completely at higher concentrations. With reference to the question whether the ancient seas which accomplished such extensive dolomitization were more concentrated than the modern ones or not, little can yet be said. On this point we must rely solely upon inference. Steidtmann[7] has presented evidence to show that the ancient seas were more highly magnesian than those of to-day. From independent lines of reasoning based upon paleogeographic evidence the writer is also led to believe that the magnesia content of the ancient seas may have been at least temporarily greater than at present. Let us consider the conditions obtaining in a constricted interior sea from which limestone is being deposited on a great scale. Fresh quantities of lime and magnesia and other salts are being introduced into this interior sea both by influx from the open ocean and from the streams draining the land. Now lime is constantly being depleted from this inland sea by lime-secreting organisms, while the magnesia and other salts tend to accumulate. It seems possible, then, that during a long period of limestone formation under these conditions magnesia might accumulate in considerable excess and that ere long extensive dolomitization might set in and continue until equilibrium was once more established.

Applying this theory now to the stratigraphic column, we actually find that many periods of extensive limestone formation in interior seas may be correlated with periods of extensive dolomitization. Witness the great dolomite masses of the Cambrian of the Appalachian province, and of the early Ordovician and of the Niagara.

As further evidence that the early seas which accomplished extensive dolomitization may have been temporarily concentrated, attention may be called to the fact that these seas in many instances were retreating and contracting towards the last, and that unless they were freely connected with the open ocean, evaporation under arid or semi-arid conditions might give rise to a considerable increase in salinity. Such a condition would seem to apply especially well to the Niagaran sea. Paleogeographic studies have shown that this sea became very much contracted towards the close of this epoch, and Clarke and Ruedemann[8] have concluded that the Guelph fauna must have inhabited a sea of abnormally high salinity. The latter fact considered in connection with the evidence of widespread dolomitization in the later stages of the Niagara seems significant.

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[6] Ohio Geol. Survey, 4th ser., Bull. 4, p. 165.

[7] *Jour. Geol.*, Vol. 19, pp. 323 and 392. 1911.

[8] *Mem. N. Y. State Museum*, No. 5, p. 117.